ECOLOGY AND CONSERVATION OF LARGE CARNIVORES IN A HUMAN-DOMINATED LANDSCAPE IN EASTERN ANATOLIA

by

Mark William Chynoweth

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STATEMENT OF DISSERTATION APPROVAL

The dissertation of **Mark William Chynoweth**

has been approved by the following supervisory committee members:

Çağan H. Şekercioğlu	, Chair	**4/24/2017** Date Approved
Frederick R. Adler	, Member	**4/24/2017** Date Approved
Paul Beier	, Member	**5/15/2017** Date Approved
Jack Longino	, Member	**4/24/2017** Date Approved
William Newmark	, Member	**4/24/2017** Date Approved

and by **M. Denise Dearing** , Chair/Dean of

the Department/College/School of **Biology**

and by David B. Kieda, Dean of The Graduate School.

ABSTRACT

Conservation of biodiversity is rapidly changing as a result of increased impact of human activity on the natural world. At the beginning of a new epoch – the Anthropocene – the cumulative effect of population growth and natural resource consumption has left no corner of the planet unaffected by humans. Impacts can be observed on a global scale, such as climate change, ocean acidification, and nitrification and also on a local scale including habitat destruction, community composition, and pollution. These impacts are restructuring ecosystems into novel systems that require creative approaches to conserve ecosystem processes and maintain biodiversity. Large mammalian carnivores represent a clade of organisms that has a varied ability to survive in human dominated landscapes. For my dissertation, I examined community structure, movement, and abundance of brown bears (*Ursus arctos arctos*), gray wolves (*Canis lupus*), and Caucasian lynx (*Lynx lynx dinniki*) in a human dominated landscape in eastern Turkey. From 2013-2016, I surveyed for all medium-large mammal species using remote cameras deployed in a fragmented forest patch near Sarıkamış, Turkey. Occupancy estimates reveal a mammal community dominated by large carnivores, humans and livestock, and lacking a natural prey base. During 2011-2016, I collared 28 bears, 11 wolves and 2 lynx and used species-specific seasonal resource selection functions to assess habitat selection patterns. I found that all three species use of habitat varies between seasons and is strongly linked to elevation and slope. By identifying critical habitat for all three species, I have prioritized a specific area for conservation efforts in the future. To estimate the minimum population size of brown bears in my main study area, during 2013-2015, I used scat detection dogs to collect 1,520 bear scat samples for genetic analysis, and using 8 polymorphic microsatellite loci, I identified 27 unique multilocus genotypes and expected heterozygosity of 0.70 as a proxy of genetic diversity. I also conducted opinion surveys in 2014 and combined results with surveys conducted 2006 and 2010 to understand the perspective of the local community about large carnivores. Lastly, I propose a prioritized list of future conservation plans for large carnivore conservation in the human-dominated landscape of Sarıkamış Forest, eastern Anatolia.

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CHAPTER 1

INTRODUCTION

Here, I provide a concise description of the three major themes of my doctoral dissertation: (*1.1*) large carnivores, (*1.2*) human-dominated landscapes, and (*1.3*) large carnivore conservation in the Anthropocene, and summarize the chapters of this dissertation (*1.4*).

1.1 Large Carnivores

Large carnivores are a distinct group of mammals defined by body mass and diet; they are naturally rare and typically occupy the upper trophic levels of food webs. Some species are well-studied, and their ecology and natural history are well-known, while other species are among the least studied in the world because they are cryptic, inhabit remote regions of the world, or present challenges to observe or study. Some of these factors contribute to the lack of data and subsequently, to the somewhat contentious issue of how these animals impact the ecosystems they inhabit. Contemporary research suggests that apex predators play a central role in shaping ecosystems through trophic cascades and other top-down controls (Estes et al. 2011, Ripple et al. 2014, Svenning et al. 2016). However, some researchers have questioned the quality of data and subsequent conclusions about the impact of large carnivores on ecosystem function (Mech 2012, Dobson 2014). A limiting factor for many large carnivore studies – due to traits described above – is the small sample size and short duration of most research initiatives (Ripple et al. 2014, Allen et al. 2017). Moving forward, more rigorous and long-term studies in understudied regions of the world will help us understand how large carnivores shape the ecosystems they inhabit (Ford and Goheen 2015).

Human-wildlife conflict is another critical barrier to large carnivore conservation and management (Treves and Karanth 2003, Chynoweth et al. 2016). This conflict is a result of different stakeholder opinions, along a broad ideological gradient, about carnivore presence, management, and conservation. These cultural and political attitudes impact large carnivore science and management more than those of most other species. This is particularly challenging because the presence of large carnivores often leads to polarization between people who value these animals as charismatic megafauna and those who view them as a threat to livestock husbandry, game populations, or human well-being (Sjölander-Lindqvist et al. 2015).

Regardless of personal opinions about large carnivores, a scientific approach is crucial to accurately assess their roles in our changing planet, and we must be cautious not to use science to justify personal beliefs (Mech 2012). The reality is that the science of large carnivores in human-dominated landscapes is undeveloped, and many seemingly fundamental concepts and terms, such as *trophic cascade* and *apex predator* are still being defined (Wallach et al. 2015, Ripple et al. 2016). Furthermore, as we struggle to understand large carnivores' relationships and impacts, most populations are in global decline (Ripple et al. 2014), adding to the urgency of taking conservation action.

1.2 Human-Dominated Ecosystems

Human impact on ecosystems ranges from global change phenomena, such as climate change, alteration of nutrient cycles, and invasive species (Vitousek et al. 1997), to local impacts including water quality, habitat destruction, and defaunation (Dirzo et al. 2014). All these impacts are increasing due to a burgeoning human population, which, coupled with increasing global natural resource consumption per capita, is driving the restructuring of ecological relationships and the creation of novel and hybrid ecosystems (Estes et al. 2011). In these modified landscapes, wildlife species face new challenges and some species thrive while other species become locally extinct.

Though research on large carnivore species in human-dominated landscapes is becoming more frequent, most studies maintain a traditional focus on species relationships in natural areas (Kuijper et al. 2016). Furthermore, when biodiversity patterns in human-dominated landscapes are studied, they are usually conducted in North America and Western Europe. Developing nations, where population growth and land alteration are potentially greatest (Bilsborrow and Ogendo 1992), are disproportionately understudied yet harbor some of the world's most important and threatened biodiversity (IUCN 2016). Therefore, as a scientific community, we are data-rich in a small proportion of protected areas and data-poor in human-dominated landscapes, which currently encompass most of the world.

1.3 Large Carnivore Conservation in the Anthropocene

The science behind large carnivore ecology, conservation, and management has evolved to incorporate a wide variety of strategies and solutions to achieve established goals. With the technology available today – given unlimited financial resources – an individual or agency can produce comprehensive data to inform scientists and managers about carnivore movement, resource use, density, gene flow, and other important aspects of wildlife ecology. In the coming years, large carnivore research needs to focus more on populations in human-dominated landscapes and novel ecosystems to understand mammal community structure and how large carnivores impact ecosystems.

Large carnivores have varying levels of success in these novel ecosystems (Kuijper et al. 2016), depending on species-specific life history traits and habitat requirements. A major advantage for any species in the Anthropocene is the ability to exploit anthropogenic food resources, particularly predictable sources (Oro et al. 2013, Newsome et al. 2015, Cozzi et al. 2016). Waste management, which yields large quantities of such predictable food sources, has become a major issue that is known to affect animal movements and populations (Sutherland et al. 2016). Many large carnivore species, (e.g., bears and wolves) are known to use these and other anthropogenic resources to sustain and even increase populations.

One important concept that will be revisited in the final chapter of this dissertation is increasing the social carrying capacity of large carnivores. We are learning that some species are able to coexist with humans and in human-dominated landscapes. However, for successful, sustainable cohabitation to occur, humans must act on a desire to coexist, instead of merely creating the ecological carrying capacity to do so. The general population must understand that the presence of these animals on the landscape will result in some personal losses (e.g., livestock), but also that many tools available to them can reduce human-wildlife conflict and maintain large carnivore populations.

1.4 Dissertation Chapter Summary

The overall objective of my field work was to understand the basic ecology of three large carnivore species, gray wolf (*Canis lupus lupus*), Eurasian brown bear (*Ursus arctos arctos*), and Caucasian lynx (*Lynx lynx dinniki*), in greatly understudied Caucasus and Iran-Anatolia global biodiversity hotspots in eastern Turkey and to use this information to guide conservation efforts in the region. All three species are widespread outside urban areas throughout Eurasia, and the same species (*Canis lupus*), related subspecies (*Ursus arctos horribilis*), or sister taxa (*Lynx canadensis*) inhabit large regions of North America.

To address these objectives and hypotheses, six chapters, written as scientific manuscripts, entail the body of the dissertation. First, a review of camera trapping in ecology and conservation provides a detailed look at how this method is changing the field of conservation biology and is contributing to the conservation of mammals worldwide. This chapter was submitted as my preliminary exam for the PhD program in the Department of Biology at the University of Utah, and has been submitted to the journals *Biological Conservation*, *Conservation Biology*, and *Environmental Conservation*. This review is being revised for resubmission for publication.

The third chapter of the dissertation is a conservation ecology camera trap study of the medium-large mammal community in our study region. As a long-term monitoring effort, this study represents a comprehensive summary of the mammal community and the unprecedented high levels of human activity in the Sarıkamış-Allahuekber Mountains National Park. It also documents, for the first time to my knowledge, an ecosystem that supports large carnivores in the absence of a natural prey base. This manuscript will be submitted for publication in the journal *Ecology*.

Third, a resource selection function for all three large carnivore species is developed to quantify how large carnivores are using resources within their home ranges. I used a species-specific, seasonal model to examine what resources drive large carnivore habitat selection in Sarıkamış Forest in eastern Turkey. Results are used to identify the largest tract of suitable habitat for all three species, which will become a priority to be designated as a protected area. This manuscript will be submitted for publication in the journal *Conservation Biology*.

Fourth, I describe a genetic approach to obtaining a minimum population estimate for brown bears in the study area. This work is ongoing and our sample collection will allow us to estimate population size for multiple species and consider important concepts in conservation biology such as gene flow, genetic bottlenecks, subspecies status, and genetic connectivity. Preliminary results identified 27 unique multilocus genotypes which suggests a minimum population size of 27 bears.

Fifth, opinion surveys were conducted with 942 people to help understand the opinion of local communities about large carnivores. Results suggest that human perceptions of wildlife are a barrier to conservation and management of wildlife populations in Sarıkamış forest. The research, education, and outreach framework outlined in the manuscript can be used to address human–wildlife conflict across Turkey and guide ongoing conservation efforts of Turkey's existing, and increasingly threatened, large carnivores. This manuscript has been published in the journal *Turkish Journal of Zoology*.

A final chapter discusses the management implications of this work and how a multifaceted approach can provide the best guidance for large carnivore management and overall biodiversity conservation. As a conclusion, this chapter summarizes some of the main findings from previous chapters and also synthesizes this work to generate solutions for applied conservation in Sarıkamış forest. It also takes a broad approach to apply these results to similar areas around the world that are understudied, human-dominated, and at high risk of biodiversity loss.

My overall goal in this dissertation is to provide a comprehensive analysis of large carnivore ecology, conservation and management in a human-dominated landscape in Eastern Anatolia. While this work focuses on one study site in an understudied region, results and conclusions stated here can be applied to many areas that large carnivores inhabit, including species not discussed here. As humans impact more wilderness areas across the planet, there will be more human-wildlife conflict and we will lose more species, unless we use ecology and conservation biology research to guide conservation efforts.

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CHAPTER 2

IMPROVING THE USE OF CAMERA TRAPS IN ECOLOGY AND CONSERVATION

2.1 Abstract

Camera traps are a common tool in animal ecology research, helping answer questions on wildlife presence, abundance, trends, and conservation. Because they document elusive species, capture diurnal and nocturnal animals, and collect data in remote field locations without human presence, these motion-triggered camera traps are an effective, noninvasive biodiversity survey method often used in conservation monitoring. As ongoing technological advances allow cameras to collect continually more photos and video, analysis techniques for large amounts of data are also evolving. However, researchers often use camera traps without defining a specific conservation question or concern or considering alternate, more appropriate methods. In this review, we describe conservation and ecology questions suitable for camera trap studies and their importance for biodiversity monitoring and conservation assessments. By comparing camera traps to other methods, we outline how researchers can match biological questions with appropriate technology.

2.2 Introduction

Digital camera traps are a relatively low-cost tool for research and management, with negligible impacts on target species or the environment (O'Connell et al. 2011). Over the past decade, use of camera traps in conservation biology, ecology, monitoring and biodiversity assessments has grown significantly (McCallum 2013, Burton et al. 2015) motivating a need to assess how this approach can achieve objectives for a range of research agendas. Without appropriate research design, advance planning, and power analyses, conservation biologists often collect high volumes of data that they are unable to use to either inform their management of vulnerable species and systems or answer the conservation questions that initiated their research (Hebblewhite and Haydon 2010). To understand which conservation goals can be best addressed using camera traps, clear research questions must first be identified. For efficient use of time and resources, researchers must distinguish the reasons for camera trapping programs and choose appropriate study designs and analyses for conservation monitoring programs (Jones et al. 2013).

Our review of camera trapping studies from 1975 to 2014 (Appendix A) reveals that publications have increased at an exponential rate (Figure 2.1) around the world (Figure 2.2). Camera traps have been used to study mammals, birds, reptiles, and insects; however, 84% of the 529 scientific papers using camera traps targeted mammals. These studies had at least one of five primary objectives: documenting species presence/richness, quantifying activity patterns, estimating density, evaluating relative abundance, and/or estimating occupancy. In this paper, we discuss the appropriate use of camera traps for each of these objectives. Our goal is to inform conservation biologists of the advantages and disadvantages of camera traps, to assist in appropriate choice of method and study design, and to review the contribution of camera trapping studies to conservation biology.

2.3 Literature Review Methods and Results

2.3.1 Literature Review Methods

A systematic search of peer-reviewed literature published between 1975 and 2016 was conducted using search terms related to camera traps and animal ecology (Table 2.1). Every combination of these terms was used in a search of the ISI Web of Knowledge search engine. Each article was reviewed to confirm that it discussed camera traps. The database included: publication year, article title, journal name, target taxa, study country, paper type, primary objective, analysis, and number of camera trap days.

2.3.2 Literature Review Results

Our literature search resulted in 529 papers published across 146 journals, with 47 journals having more than two articles (see top 10 journals in Table 2.2). Research was conducted in 70 different countries (Figure 2.2). Target taxa included mammals, birds, herpetofauna, insects and multiple taxa (Table 2.3). The majority of articles covered studies of mammals (84.1%), most of which belonged to the order Carnivora (56.2%), the majority of which were felids (58.8%). Peer-reviewed publications increased exponentially, with the first article published in 1993 and over 130 articles published in 2014. Conservation of species and ecosystems is frequently cited as the main focus, with "conservation" being included in the title or as a keyword in 87% of articles. The primary objective of most studies was documenting species presence (36.7%). Papers also had primary objectives of estimating activity (21.0%), density (19.8%), relative abundance (8.7%), and occupancy (4.2%). Total survey effort, or camera-days, had a median of 1,789 days; however, 40.7% of articles did not report total number of days or survey effort.

2.4 Biological Objectives

Camera traps have been used to monitor many species and objectives in animal ecology. Here we focus on the most common study objectives: presence, abundance, density, occupancy and activity. However, even for well-studied species such as tigers, few studies go beyond baseline assessments (Linkie et al. 2010). As this method evolves, conservationists are increasingly using these parameters to test hypotheses and address a range of questions including human impacts on wildlife (Main and Richardson 2002), monitoring biodiversity (Waldon et al. 2011), reproductive ecology (Farhadinia et al. 2009), and nest predation (Bayne and Hobson 1997, Beck and Terborgh 2002, Vilardell et al. 2012).

2.4.1 Documenting Species Presence

Documenting species presence or absence--the objective of most camera trap studies--is crucial to discovery (Rovero et al. 2008), rediscovery (Yamada et al. 2010), confirmation (Lhota et al. 2012), and range expansion (Chynoweth et al. 2015) of known or unknown species. Presence is a powerful indicator pertinent to monitoring elusive and endangered species, and photos of these species are invaluable for education and public outreach. Effects of human activity on species and ecosystem dynamics in remote areas (Muhly et al. 2011) and conservation threats, such as the impact of poachers on wildlife populations, can also be monitored (Jenks et al. 2012).

Photographic evidence often renders species presence indisputable. However, photos of animals can be misinterpreted or indecipherable, leading to spurious claims of new species (Meijaard et al. 2006). These claims, along with apparent range expansions and rediscoveries, may be a result of lack of baseline information and increasing density of camera traps (Dobson and Nowak 2010). Researchers must acknowledge that non-detection (i.e., absence) is related to detection probability, which is almost always <1, and a few isolated individuals of target species may exist (Tilson et al. 2004).

Though several established methods effectively document species presence, comparison studies suggest that camera traps have higher probabilities than hair tunnels (O'Connell et al. 2006, Paull et al. 2012), cubby boxes (O'Connell et al. 2006), patrol observations (Burton 2012), and line-transect surveys (Trolle et al. 2008) for detecting smaller, solitary, and nocturnal species. However, studies incorporating track plates have shown that species richness and recording rates correlate with camera trapping results (Espartosa et al. 2011). In some cases, track plates were more effective (Hackett et al. 2007) and detected more individuals (Rosas-Rosas and Bender 2012). Yet, with technological advances, remote cameras require less maintenance and may be more cost effective than track plates for studies >1 year (Ford et al. 2009). An alternative method for detecting presence is genotyping by scat collection, which has produced consistent (Galaverni et al. 2011) and sometimes better (Harrison et al. 2002) detection probabilities than camera traps. Under proper weather conditions, snowtracking surveys have the highest probability of detection for species active in winter (Gompper et al. 2006).

Study design for documenting species presence does not necessarily need to be systematic and can be targeted at specific sites or use species-specific baits to maximize detection probability. If the goal is to produce estimates of abundance or density, a different study objective and more rigorous study design is required. A minimum number of cameras is not required, but having more cameras increases detection probability. To maximize detection, complementary survey techniques should be used (e.g., sign, snow tracking).

2.4.2 Relative Abundance Index (RAI)

Presence data can be used to generate a Relative Abundance Index (RAI) by summing detections for each species for all camera traps over all days, dividing it by the total number of camera trap nights, and typically multiplying this fraction by 100 (O'brien 2011). This approach is attractive to conservationists because of its simplicity; however, in recent years it has been scrutinized for being an inappropriate and unreliable method (Sollmann et al. 2013a). This index is known to produce biased estimates based on heterogeneous detection probabilities (Jennelle et al. 2002, Sollmann et al. 2013b), and as a result, its use needs to be justified as the only reasonable alternative to other methods (O'brien 2011).

The application of the RAI relies on the assumption that this index is directly related to true species abundance (O'Brien et al. 2003). The majority of RAI studies aim to estimate abundance at a single point in time at a specific site (e.g., protected area), but this index has also been used as an abundance proxy to study a variety of ecological processes including habitat use (Bowkett et al. 2008), human impacts (Kinnaird and O'brien 2012), temporal population dynamics (Jenks et al. 2011), and activity patterns (Ramesh et al. 2012).

The main issue confronting RAI is the problem of detectability. Detectability varies among and within species and is considered a major source of bias (Larrucea et al. 2007). Variations in detection probability due to species differences, home range size, study design, and temporal patterns have all been shown to bias RAI estimates (Sollmann et al. 2013b). Calibration of abundances can improve reliability, but requires periodic calibration with independently derived estimates in a double sampling design (O'Brien et al. 2003), rather than from another site or species.

Study design for RAI surveys should aim to limit the effect of variation in detection probabilities to account for the main deficiency of this approach (Sollmann et al. 2013b). Once the study area is determined, cameras should be placed at distances smaller than the home range diameter of target species to prevent false negatives. The number of cameras necessary depends on study area extent and target species, but should cover the area uniformly to maximize detection probability. To calculate RAI or trap rate, only species presence data and trapping effort are needed. Therefore, methods described in the previous section (3.1) can be used in lieu of camera traps. Track plates, hair traps, and other signs have produced reliable abundance estimates (Jhala et al. 2011) and may be appropriate in the face of financial and temporal constraints.

2.4.3 Density Estimates and Individual Recognition

Density estimates are a common objective of camera trapping studies (20% of papers reviewed) and may be the most sought-after population parameter (O'Connell et al. 2011). Density estimates allow for easy comparisons between sites and years or extrapolation to larger areas (Bellan et al. 2013). If individuals can be identified in a population, capture-recapture methods can produce reliable estimates for a study area. Three main types of capture-recapture population models are used to estimate abundance: (*i*) closed—no birth, death, immigration or emigration (O'brien 2011), (*ii*) open—losses and recruitments are allowed (Gutiérrez-González et al. 2012), and (*iii*) spatially explicit—including spatial characteristics such as home range (Gardner et al. 2010). Abundance estimates from these models can be converted to density estimates by estimating the area sampled during the survey (Maffei and Noss 2007).

The sampling area for density estimate studies is typically set up in a grid-like system with the outermost trap locations representing the study area boundary. To estimate effective sampling area, the simplest approach is to draw a concave polygon by connecting outermost trap locations. However, this fails to include ingress from outside animals. A more appropriate approach is to estimate a buffer around this polygon. Though no consensus exists on calculating this area, a buffer of mean maximum distance moved (MMDM) of the target species is common. MMDM can be estimated from camera trap data, spatially explicit capture-recapture models (SECR), or estimates based on auxiliary telemetry data. The MMDM method may over-inflate density estimates (Soisalo and Cavalcanti 2006), which has led to the arbitrary but frequently used ½MMDM approach. Neither has a theoretical basis (Obbard et al. 2010). Auxiliary telemetry data, typically available from other studies on target species, is most effective at estimating MMDM (Dillon and Kelly 2008, Núñez-Pérez 2011).

Early in camera trapping science, two landmark papers estimated density of tigers by identifying individuals with unique pelage characteristics (Karanth 1995, Karanth and Nichols 1998). This approach has been extended to a variety of species to identify individuals based on spots (Jackson et al. 2006), stripes (Singh et al. 2010), muzzle markings (Mazzolli 2010) and other forms of unique pelage (Caruso et al. 2012). Additionally, capture-recapture methods are possible if animals are captured and tagged with artificial markings such as ear tags or GPS collars (Jordan et al. 2011, Weckel and Rockwell 2013). However, density estimation is not a completely refined analysis technique (Foster and Harmsen 2012). Study design issues related to sampling area, camera spacing, and detection probability may introduce significant biases (Dillon and Kelly 2007).

Individual identification is subject to researcher bias (Oliveira-Santos et al. 2010), and efforts have been made to incorporate a more rigorous Bayesian approach to individual identification (Stafford and Lloyd 2011). Bilateral photo identification records from single trap stations can introduce inconsistencies due to bilateral asymmetry in coat patterns, but modeling approaches to combine left- and right-sided photos are being developed (McClintock et al. 2013). A common and simple resolution is to modify study design to include two cameras at each station (Negrões et al. 2012).

Several reviews have focused on analysis techniques (Sharma et al. 2010, Obbard et al. 2010, Foster and Harmsen 2012), improving current capture-recapture analysis (Royle et al. 2009), new techniques including Bayesian inferences for arbitrary sample sizes

(Gardner et al. 2010), and maximum likelihood approaches (O'Brien and Kinnaird 2011). SECR models use a hierarchical approach to model detection probability and have produced more accurate density measurements in some studies (Kalle et al. 2011, Blanc et al. 2013). These advances in density estimators work only for the relatively few species that can be individually identified by coat patterns. Techniques to estimate density without individual identification have been proposed (Carbone et al. 2001, Rowcliffe et al. 2008, Manzo et al. 2012), but have not been without criticisms (Foster and Harmsen 2012).

2.4.4 Occupancy

Reliable density estimates require rigorous study design and knowledge of advanced statistical techniques. An alternative approach is occupancy modeling, an established method to model the probability of a site being occupied by a species (MacKenzie et al. 2006, O'Connell and Bailey 2011). Occupancy uses presence/absence data from independent replicate surveys under the assumption that the population is closed during the survey period. Results provide a probability of occupancy across space based on researchers' definition of the site. In addition, surveys can be conducted over time and space to elucidate how habitat covariates impact species occurrence. A major advantage of occupancy modeling is that it explicitly estimates and models detection probability (Jones 2011). Generally, there is a positive relationship between occupancy and abundance, and occupancy has been used as a proxy for abundance in studies of niche partitioning (Di Bitetti et al. 2010), impact of human disturbance (Mohamed et al. 2013), and predator-prey dynamics (Silva-Rodríguez and Sieving 2012). This approach requires smaller sample sizes and is therefore typically less expensive (MacKenzie et al. 2006). A rich literature exists on modeling species occupancy with a wide variety of presence/absence data (Vojta 2005, MacKenzie et al. 2006) and has been used in a number of camera trap studies (Erb et al. 2012, Gopalaswamy et al. 2012a, Schuette et al. 2013).

Because occupancy can be estimated given any type of presence data, methods described in the previous section (3.1) can be substituted for camera traps. Given adequate detection probabilities, site occupancy estimated from camera traps is similar to estimates from cubby boxes, hair traps and track plates (O'Connell et al. 2006). Sign surveys (e.g., scat) have proven effective at generating reliable occupancy estimates (Gopalaswamy et al. 2012a), and may be more effective than camera traps at estimating occupancy at a landscape scale (Karanth et al. 2011).

Study design for occupancy models requires a grid system camera array that provides a representative sample of the study area. At least 20 sampling units (grid cells) should be sampled, but occupancy models allow for stations to be shifted between units, given that they are present at each location long enough to collect sufficient data (O'Connell and Bailey 2011). Cameras should be spaced at a distance greater than the minimum of the diameter of the target species' home range. Information on environmental conditions for each grid cell also needs to be collected if researchers choose to include habitat covariates in the occupancy model.

2.4.5 Activity Analysis

Activity patterns of target species can also be observed using camera trap data (21% of reviewed papers) to elucidate diel and seasonal activity patterns and understand interspecific competition and niche analysis. Camera traps allow researchers to record multiple species over long periods with minimal disturbance (Ramesh and Kalle 2013). Much work has been done with sympatric species, such as felids (Foster et al. 2013) and observation of predator-prey dynamics (Weckel et al. 2006, Ford and Clevenger 2010, Linkie and Ridout 2011). Especially important for conservation, human impact on animal activity, including human-wildlife coexistence, has also been investigated (Carter et al. 2012). However, co-occurrence does not necessarily equal coexistence (Harihar et al. 2013), and camera trapping data may fail to capture important factors that determine species activity and distribution.

A presumed benefit of camera traps is that wildlife are not impacted by equipment. However, camera traps should not be considered an entirely nonintrusive approach. The sound (shutter), sight (flash), and smell (human scent) from camera traps may impact the behavior of animals, and even lead to trap shyness (Larrucea et al. 2007). Furthermore, because animal behavior can be difficult to interpret from a single photograph, motivations are often inferred and may lead to false interpretation.

Though camera traps enable researchers to gain new insights into the activity patterns of wild animals, other approaches also produce reliable data. Most telemetry collars are now equipped with an activity sensor that monitors dual axis movement of an animal's neck at high temporal resolutions (5 min intervals). Combined with movement data from GPS location, detailed animal activity can be observed. More recently, Crittercams©

have been deployed on large mammal species to document previously unknown activity (Şekercioğlu 2013). With increasing amounts of data being collected remotely, the value of firsthand field observations cannot be underestimated. Biologists must ensure they do not become distanced from critical, field-based knowledge of animal ecology (Hebblewhite and Haydon 2010).

Study design for activity surveys focuses on documenting temporal and seasonal presence data and therefore should strive to maximize detection probabilities for target species. Camera placement on game trails and other areas frequented by animals may increase captures. To avoid biases associated with detection, study design must aim to have equal detection probabilities between species.

2.5 Importance of Camera Trapping for Biodiversity Monitoring and Conservation

Camera traps have become invaluable tools for conservation projects around the world. One of their most valuable features is their ability to deploy a trap that will record thousands of images with limited labor requirements and remain active for months (O'Brien 2016). This is particularly useful in study areas characterized by remoteness, conservation interest and/or lack of data. Camera traps have documented images of new species (Rovero and Rathbun 2006), range extensions (Chynoweth et al. 2015), poaching and other illegal activity (Jenks et al. 2012), or preliminary fauna inventories for understudied areas (Tobler et al. 2008). These images can impact short- and long-term agendas for conservation organizations.

In the past decade, much work has been done to improve the scientific rigor of camera trapping studies. Camera trapping science is evolving rapidly, and scientists and practitioners emphasize that carefully executed study designs can yield informative parameters we have described in the sections above. However, the importance of simple, inexpensive camera deployments that can revolutionize conservation projects with budgetary restrictions should also be recognized. It has been suggested that there are two categories of camera trap studies: (1) science, understanding how an ecosystem works, and (2) management, moving an ecosystem from less to more desirable states (Nichols et al. 2011). We assert that conservation outreach and environmental education constitute a third category. While other experts have suggested that photos are the means to an end goal of informing the larger process of science and management (Nichols et al. 2011), we also affirm the value of photographic records of elusive species. For example, an existing conservation project in eastern Turkey initially deployed four camera traps at a study site in 2006. The documentation of an unexpected relative abundance of large carnivores and the scarcity of their prey species has led to national and international support for a large-scale monitoring project for mammals, catalyzed the government to designate Turkey's first wildlife corridor, and the project has become a conservation icon in a country experiencing a major biodiversity crisis (Şekercioğlu et al. 2011). The project has since evolved into a more rigorous study with a network of 40 camera traps being systematically deployed over a multiyear period.

Camera trap photos and videos are also effective public outreach tools that raise awareness about important study sites, vulnerable species, and conservation priorities of local and global organizations or governmental agencies. A single photo published via social and traditional media can deliver important conservation messages to thousands of people. The authors share camera trap photos and project updates on Facebook and Instagram, where one photo can be viewed by over 5,000 individuals in a five-day period. Public outreach opportunities extend to citizen science approaches in which members of the public deploy cameras or identify species in camera trap photos. Several large-scale camera trapping efforts, such as the Tropical Ecology Assessment and Monitoring Network (TEAM; www.teamnetwork.org; also see Fegraus et al. 2011) and Smithsonian Wild (see http://siwild.si.edu), have already made progress through citizen science efforts. Three case studies outlining successful camera trap projects are available in supplemental material (Appendix B).

2.6 Future of Camera Trapping in Conservation Biology and Ecology

In the past two decades, camera trapping has emerged as an important subfield of conservation biology and ecology, and the exponential increase in studies is likely to continue. Research questions on presence/absence and basic ecology of animals are valuable to conservation efforts. However, further development of study designs, analyses and a standardization of reporting camera trap results is needed (Meek et al. 2014). Currently, few studies go beyond baseline assessments (Linkie et al. 2010), but as equipment becomes less expensive, broad scale landscape ecology studies can incorporate camera traps to address novel questions in conservation biology (Erb et al. 2012).

Our literature review highlights the benefits of camera traps as a low-cost, low maintenance, and mostly noninvasive monitoring tool for conservation biology research and applied conservation projects. Many studies in our review documented understudied species in remote areas and how significant camera trapping findings contributed to the conservation of species and ecosystems. Use the growing body of literature, conservationists can ensure they are defining questions *a priori* and making inferences using appropriate analyses and statistical techniques.

As more sophisticated studies are designed, camera traps will help shape large-scale conservation agendas, especially across protected areas (Kinnaird and O’brien 2012, Li et al. 2012). Camera trapping has been increasingly discussed as a method for conservation hotspot analyses (Kouakou et al. 2011), monitoring biodiversity (Waldon et al. 2011), comparing human dominated landscapes to natural areas (Cassano et al. 2012), and assessing how animals respond to fluctuations in human activity (Harihar et al. 2009, Mohamed et al. 2013). Camera traps have already helped biologists document unexpected wildlife presence in human-dominated landscapes (Athreya et al. 2013). If global camera trapping efforts can be standardized (Ahumada et al. 2011) and coordinated, camera traps could contribute to a comprehensive global mammal conservation strategy (Rondinini et al. 2011). Furthermore, if data management issues are addressed, meta-analyses of current data could be pursued for regional analysis of abundance and diversity (Ordeñana et al. 2010).

This review highlights two recurring issues undermining the main conservation biology questions camera traps aim to address. First, detection probability and survey effort are frequently ignored, but these elements are fundamental to the inferences that can be made from camera trapping data. Scientists, managers and conservationists should be careful when comparing or applying results from camera trapping studies that do not address these issues. Second, camera trapping may not be the most suitable method to address a given conservation biology question. Many reliable methods can document the presence of species and lead to accurate estimations of population parameters. Some of the most successful studies in our review used camera traps in conjunction with other techniques to generate estimates of target species density (Gopalaswamy et al. 2012b) and a more holistic picture of population dynamics (Palomares et al. 2012).

Given the current benefits and future prospects of camera traps to address objectives in animal ecology and conservation biology, the surge in peer-reviewed publications over the last few years is to be expected. Our literature review used only the Web of Science™ database and did not include gray literature from conservation organizations or government agencies. Inclusion would have increased our sample size of papers, but we believe that we would have reached similar conclusions. In light of the current popularity of camera traps, biologists must carefully define their questions and objectives before field data collection. Camera trapping analyses have evolved to depend heavily on careful study design, without which improper data collection severely limits analyses and subsequent inferences and consequently reduces the conservation benefits of this revolutionary method.

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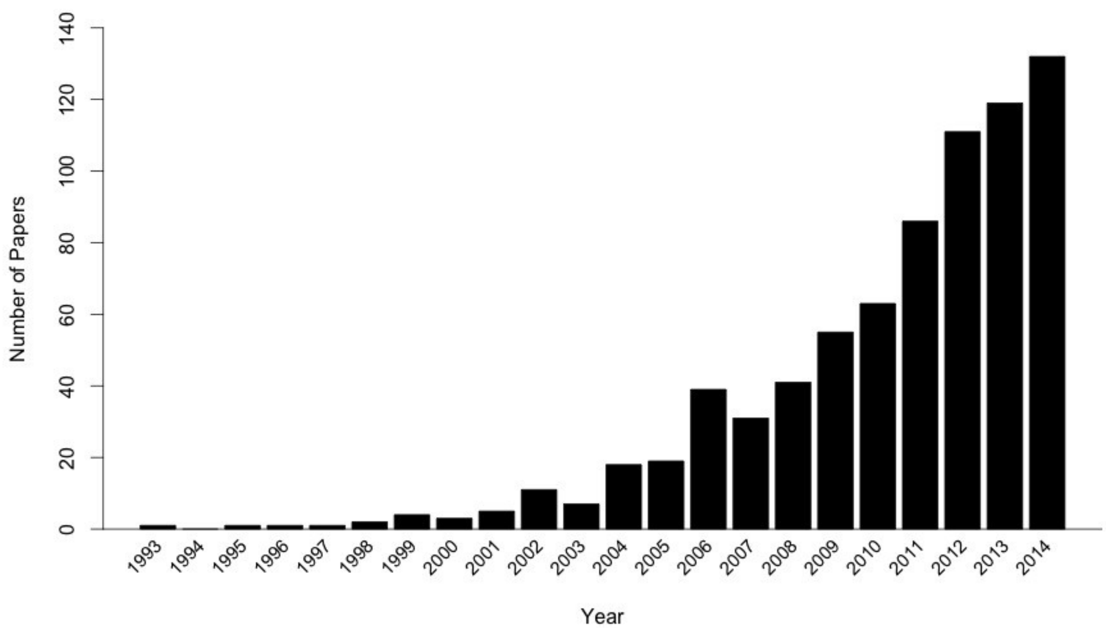

Figure 2.1. Camera trapping studies by year published from 1975-2014 based on a systematic search of key terms in ISI Web of Knowledge.

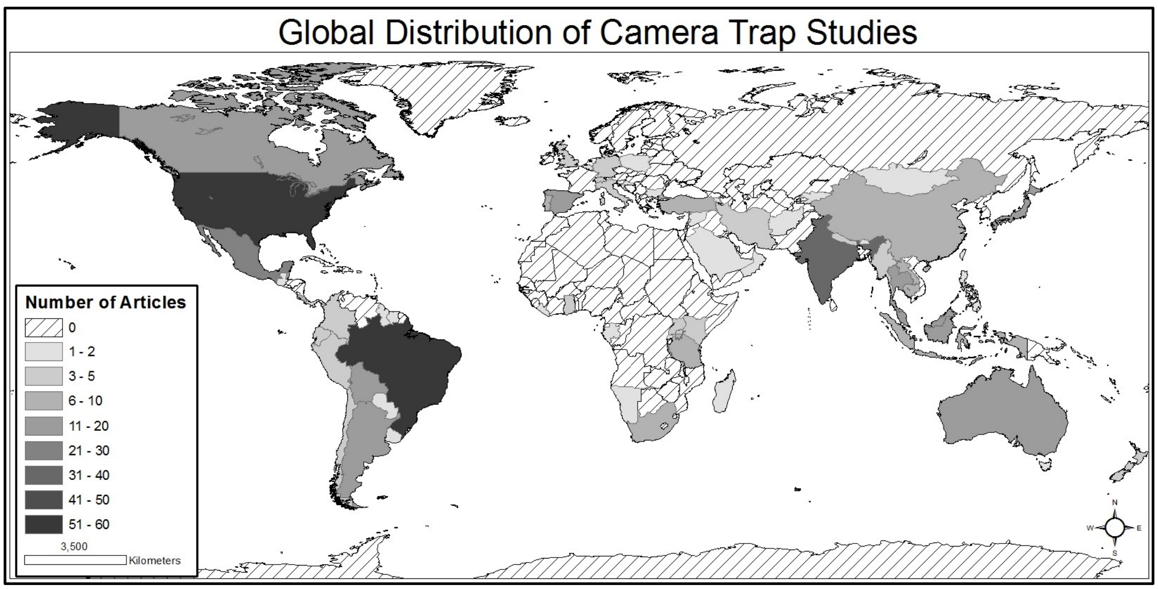

Figure 2.2. The global distribution of camera trapping studies published from 1975-2014 based on a systematic search of key terms in ISI Web of Knowledge.

Table 2.1 Camera trap and animal ecology keywords used in the ISI Web of Knowledge literature search at the University of Utah.

Camera Trap terms	**Animal ecology terms**
"Camera Trap*"	Wildlife
"Game Camera*"	Birds
"Trail Camera*"	Mammals
"Remote Photography"	Reptiles
	Amphibians

Table 2.2. Number of camera trapping articles published in the top ten journals from 1975-2014 based on a systematic search of key terms in ISI Web of Knowledge.

Journal	Number of Articles
Oryx	48
Animal Conservation	23
Biological Conservation	22
Journal of Mammalogy	17
Journal of Wildlife Management	17
Biotropica	14
Biodiversity and Conservation	13
European Journal of Wildlife Research	13
Journal of Tropical Ecology	13
Journal of Zoology	12

Table 2.3. Proportion of target taxa in camera trapping studies published from 1975-2014 based on a systematic search of key terms in ISI Web of Knowledge.

Taxa	Percent of Total Articles*
Mammal	84.1
Bird (including nest predation)	6.0
Multiple taxa	4.2
Herpetofauna	1.5
Insect	0.6
Within Mammal Order Diversity	**Percent of Mammal Category**
Carnivore	56.2
Multiple Orders	29.2
Ungulate	7.6
Rodentia	4.0
Primate	2.2
Marine	0.4
Bats	0.2
Within Carnivore Family Diversity	**Percent of Carnivore Category**
Felidae	58.8
Multiple Families	24.4
Canidae	10.8
Ursidae	3.6
Hyaenidae	1.2
Other	1.2

*Percent of total articles does not add up to 100% (96.4%) because review articles were present in the database

CHAPTER 3

LARGE CARNIVORE HYPERABUNDANCE IN AN EMPTY FOREST

3.1 Abstract

As human population and consequent ecological impact continue to grow, certain wildlife species are increasingly utilizing anthropogenic food sources to sustain and even increase their population sizes. One example is large carnivores, which are known to develop synanthropic behavior and rely on livestock, garbage, and other anthropogenic resources. To examine this phenomenon, we conducted a multiyear camera trap study in Sarıkamış-Allahuekber Mountains National Park and surrounding forest in eastern Turkey to document presence and estimate species-specific single-season occupancy for medium-large mammals in a geographically isolated and heavily degraded forest. Preliminary camera trap efforts began in 2006 with opportunistic sampling. During 2013-2016 we used a 2 km^2 sampling grid to sample approximately 326 km^2 of forested area dominated by Scots pine. Camera traps were deployed for a minimum of 45 consecutive days each year during four summer/fall field seasons. We obtained more than 50,000 images and detected 14 species of wild mammals during a total sampling effort of 12,731 camera trap days. Human activity was the most common event captured by cameras and was an order of magnitude more common than that of all other species. Gray wolves and

Eurasian brown bears were the most frequent wildlife events. Species-specific single season modeled occupancy estimates ranged across years (2013-2016) from 0.772 - 0.856 for bears, 0.53 - 0.922 for wolves, and 0.372 - 1 for lynx. Natural prey species were rarely captured, implying that these species may be functionally extinct as a natural prey base. Wild boar was the only natural prey species with sufficient data for occupancy modeling, with a range of 0.466 - 0.646 across years. Human activity was ubiquitous across the landscape, with human occupancy estimates ranging from 0.835 - 1 and livestock occupancy ranging from 0.395 - 0.498 across years. Our results suggest that in human-dominated landscapes, the combination of the scarcity of natural prey and the presence of synanthropic carnivores can result in an alternative stable state of an ecosystem in which carnivores increase in abundance while wildlife habitat quality continues to degrade.

3.2 Introduction

The growth and impact of human activity has become a dominant force on our planet (Steffen et al. 2007, Barnosky et al. 2012). During the Anthropocene, ecosystems have deviated in structure and function from previous epochs, generating novel and hybrid ecosystems that include anthropogenic impact and activity as a major contributor to ecosystem processes (Hobbs et al. 2006). One major consequence of the Anthropocene is global level defaunation, or the depletion of animals from ecological communities. A concept that has recently drawn more attention, defaunation is an increasing global threat and a major driver of ecological change that has both short- and long-term consequences (Dirzo et al. 2014).

Vertebrate megafauna are often the most susceptible to large-scale depletion, due to their large home ranges (i.e., vast habitat requirements), harvest by humans as a potential food source, and direct persecution as a result of human-wildlife conflict (Ripple et al. 2014, 2015). Loss of large vertebrates can result in the disruption of ecological interactions and trophic restructuring of an ecosystem (Estes et al. 2011). For example, extirpation of large mammalian carnivores can lead to hyperabundance of herbivores and negative consequences for producers (Terborgh 2001). Another consequence of defaunation caused by human activity is the creation of empty forests, which are devoid of mammals and maintain the appearance of intact habitat, but many species are functionally extinct (Redford 1992).

Large carnivores are one of the most imperiled mammal groups globally, and populations are absent or declining throughout much of their native range (Ripple et al. 2014). Large carnivores experience the same threats as all megafauna, but in addition, are frequently more persecuted than other megafauna because of real and perceived threats to livestock, game species, and people (Frank and Woodroffe 2001, Gross 2008). Therefore, these species have typically been the first trophic level to be removed from an ecosystem. Specialist and obligate carnivores may be the most threatened, as they are often unable to adapt to human-induced changes in ecosystem structure and function.

In response to these human-driven changes in their environment, some generalist large carnivores can change behavior to exploit human food sources and use modified habitat (i.e., synanthropy) to sustain and even increase population numbers (Newsome et al. 2015b). Synanthropy in large carnivores is well documented in many species. Coyotes, a well-known synanthropic carnivore, exhibit individual diet specialization in urban environments by altering movement and foraging strategies (Newsome et al. 2015a), and populations can reach higher densities where human food is available (Fedriani et al. 2001). Larger carnivores, including bears (Beckmann and Berger 2003) and wolves (Zlatanova et al. 2014, Newsome et al. 2016), have also demonstrated synanthropic behavior.

While some carnivores are able to inhabit—and even thrive—in human-dominated landscapes, anthropogenic food subsidies can cause dramatic changes in animal behavior and trophic cascades (Newsome et al. 2015b). These can decouple predator-prey relationships that exist in more natural systems (Fischer et al. 2012). Furthermore, when carnivores and humans inhabit the same area, there is a higher likelihood of human-wildlife conflict (Messmer 2000), which can decrease social carrying capacity (Breitenmoser et al. 2005) and increase persecution. Recent work has documented large carnivore resource use along wildland-urban interfaces and suggests that tolerance of human activity may be a limiting factor for coexistence (Bouyer et al. 2014, Moss et al. 2016). Globally, these species will increasingly encounter fragmented habitat and human-dominated ecosystems (Crooks et al. 2011). In order to gain a deeper understanding of trophic interactions and achieve important conservation goals, humans should be incorporated into trophic ecology (Dorresteijn et al. 2015).

In this study, our intent was to implement a biodiversity monitoring program in northeastern Turkey, a historically understudied region of the world that harbors globally important biodiversity (Figure 3.1; Şekercioğlu et al. 2011). To guide ongoing conservation efforts in the region, we applied a multispecies, multiyear camera trapping approach to a fragmented patch of forest in a human-dominated landscape. Our study area is representative of many other regions of the world where little or no biodiversity monitoring is occurring, and consequently, no mechanisms exist to maintain or protect existing biological resources.

Our main objective for this study was to document species presence, quantify species richness, generate species' distributions, and evaluate community composition in a patch of fragmented forest surrounding the city of Sarıkamış in eastern Turkey (hereafter "Sarıkamış Forest"). Our ongoing work in Sarıkamış Forest has documented synanthropic behavior (Capitani et al. 2016, Cozzi et al. 2016) and our preliminary camera trapping work showed a lack of natural prey species. We therefore hypothesized that generalist predators (i.e., brown bears and gray wolves) would have higher occupancy estimates than other native species. We also aimed to assess the effectiveness of the Sarıkamış-Allahuekber Mountains National Park, a protected area in the region. Based on our field observations and the small size of the park, we predicted that occupancy estimates within park boundaries would not differ from outside the park boundaries.

3.3 Methods

3.3.1 Study Area

Our study was carried out on the Kars-Ardahan high plateau in northeastern Turkey, at the intersection of Caucasus and Irano-Anatolian global biodiversity hotspots (Figure 3.1). The area (c. 550 km^2; 40°20'N 42°35'E) ranges between 1900 and 3120 m asl and is composed of fragmented forest in a matrix of agricultural and rangelands. The city of Sarıkamış (population: c. 18,000) is located in the center of the study area and on one of the two paved roads that bisect the forested area. Forest cover consists almost exclusively of Scots pine (*Pinus sylvestris* Linnaeus, 1753), while understory vegetation is scarce, with consequent scarcity of food resources for browsers. Sarıkamış-Allahuekber Mountains National Park (hereafter SAMNP; Figure 3.2) boundaries cover a total area of 225.1 sq. km., but only include 49.69 sq. km. of forest. Therefore, SAMNP is only comprised of 22.07% forest cover. Total forest cover in the region includes 328.38 sq. km. including a large expanse of forest south of the national park (248.15 sq. km.). These patches of forest represent the southernmost significant forest patch in the region extending south from the extensive forests in the Black Sea Region of Turkey.

Human activity in the forest is extensive in both time and space, limited only by harsh winter temperatures, and consists primarily of livestock grazing, harvest of forest products (e.g., fruits, pine cones, mushrooms), and legal and illegal timber extraction. Livestock is abundant in the region with cattle (Bos taurus Linnaeus, 1758), sheep (Ovis aries Linnaeus, 1758), and goats (Capra hircus Linnaeus, 1758) freely roaming rangelands from April to November (Capitani et al. 2016). About 851,445 livestock heads have been registered in the Kars province in 2012 (Ministry of Food, Agriculture and Livestock, Republic of Turkey). A notable feature on the landscape is an unfenced municipal garbage dump 3 km west of Sarıkamıs city. The dump represents a predictable anthropogenic food source, and bears, wolves, and wild boar visit the dump regularly at night (pers. obs.). A portion of the bear population has altered life history strategies to regularly use the dump, while other bears never visit the dump (Cozzi et al. 2016).

3.3.2 Survey Methods

Small-scale sampling began with preliminary and opportunistic camera trap efforts in 2006. During 2013-16, we followed a standardized protocol to sample the entire forested area (326 km^2), using a 2 km^2 sampling grid overlaid onto a forest cover map with Arc GIS 9.3 to determine camera stations. Points on the grid were visited to determine if camera trap deployment was feasible given the intense human activity throughout this forest. Theft and vandalism of camera traps were some of the most limiting factors in the completion of this study. We opportunistically targeted forest roads to maximize likelihood of capturing wildlife, but off-road areas were also sampled to determine relative use of dirt roads as movement corridors. If a site was deemed suitable, camera traps (Reconyx HC500/HC600/PC900) were deployed; a single camera was attached to the appropriately sized tree nearest the road.

Camera stations were designed to capture medium-large mammals, with cameras secured at knee to waist height and positioned to capture animals approaching at a 45-degree angle. Cameras were programmed to take 3 photos with each motion trigger with a 60-second delay. Vegetation that could trigger cameras was removed from the area, and bait was never used in the trap area. Cameras were deployed for a minimum of 45 consecutive days during each of four summer-fall field seasons (2013-2016). National security measures posed a significant barrier to a deploying and checking camera traps on a regular basis. As a result of this and additional permitting issues, we checked cameras sporadically over the course of deployment to replace batteries and download photographs.

3.3.3 Data Processing, Statistical Methods, and Occupancy Estimation

At the end of each field season, cameras were recovered and data from images were extracted and classified using CAMERABASE software (Tobler 2010). Vandalism and theft caused many cameras to be removed from our final database. We only included camera stations in our analysis that were active for >50% of each sampling season and a minimum of 45 days. After classifying all images, we defined an independent species event as any sequence of photos of a single species within 60 minutes.

Occupancy is defined as the proportion of points in the site where a species is expected to occur, does not require individual recognition, and is often a useful surrogate for abundance (Rovero and Marshall 2009). Modeling occupancy allows for heterogeneity in detection probability among survey sites (MacKenzie et al. 2006a). We used single-species single-season occupancy models to estimate occupancy for all species with adequate data. We modeled single-season occupancy (Ψ) and detection probability (p) where p was defined as the probability of observing a species during a survey period if it was present.

To satisfy the need for temporally replicated data, we created a detection history of whether each species was observed by a camera trap at each station during each 5-day period throughout the survey resulting in approximately 18 sampling occasions per season (18.0 +/- 2.0). Models were solved by maximum likelihood estimation (MLE) via R statistical software (R Core Team 2016) using the *unmarked* package (Fiske and Chandler 2011) to estimate the probability species *i* occurred within the area sampled by a camera station during our survey period (i.e., occurrence), while accounting for incomplete detection (MacKenzie et al. 2002, 2006b). Problems with research permits and political unrest limited when we could access the field site. Therefore, we used the only 3-month period of sampling that was consistent across 2013-16 sampling seasons, which was August 1st – November 1st.

We limited occupancy modeling by species based on two factors. Only species that were captured at a naïve occupancy equal to or greater than 0.1 (>10 % of the working cameras) were including in occupancy estimates since studies have shown that occupancy estimates are not accurate for species recorded in less than 15-20% of the cameras (Rovero et al. 2014). Also, species need to be sampled with sufficient detection probability. We excluded species from occupancy modeling with estimated detection probability less than 0.1 for at least 2 of the 4 years (Rovero et al. 2014).

3.4 Results

Across all survey years, including preliminary years, a total of 14 mammal species (Table 3.1) were identified from 66,930 images containing wildlife (6,679), humans (24,207), or domestic animals (10,190) during 12,731 trap nights (Table 3.2). Remaining photos were false triggers likely caused by vegetation moving in the wind. During 2013-2016 survey years, humans (on foot, horse, or vehicle) were the most common event and were captured on 91.3% (+/- 8.5) of the camera stations (Figure 3.3). Domestic species (livestock and dogs) were the second most common species, with cows being most frequent. Brown bears, gray wolves, wild boar, and Caucasian lynx, respectively, were the most commonly captured wildlife species. Natural prey species were rare; boar were present at low capture rates, and Eurasian hare and red squirrels were infrequent. Notably, roe deer were captured in only two surveys (Preliminary: 2009-2012 and 2015), with <5 events in each. Large carnivore and natural prey species have a strong nocturnal activity pattern that contrasts with the strong diurnal pattern of humans and livestock (Figure 3.4). Species-specific occupancy estimates between years for bears, wolves, lynx, boar, livestock, and humans are variable but consistent (Figure 3.5).

3.4.1 National Park Boundaries

Based on available data, we were unable to assess the effectiveness of SAMNP due to lack of successful camera trapping efforts within the park boundaries. Camera theft in the national park was a major limitation to generating enough data to compare these two areas. In addition, safety concerns prevented access to the park during several field seasons. In some years, all cameras in the national park were damaged or stolen, while in other years only one or two cameras were retrieved, leading to inadequate data for occupancy modeling.

3.4.2 Community Level Summaries

Single-species, single-season occupancy estimates by trophic level reveal a novel mammal community structure characterized by hyperabundance of large carnivores (including the omnivorous brown bear) and absence of natural prey (Figure 3.6). Wild boar was the only natural prey species of large carnivore for which detection histories allowed for occupancy estimates to be generated. Livestock (cows, goats, sheep, donkeys, horses) were pooled together and represent the only herbivores present in the system with high enough detection rates to allow for occupancy modeling.

3.5 Discussion

Our results suggest that the conditions in Sarıkamış Forest represent an alternative stable state characterized by large carnivore hyperabundance in a human dominated ecosystem. To our knowledge, this is the first time a system with a stable large carnivore population exists with an extremely limited natural prey base. In line with contemporary large carnivore research, our results suggest that the ecological impacts of large carnivores are not straightforward (Allen et al. 2017), especially in human-dominated landscapes (Dorresteijn et al. 2015), and presence of large carnivores is not necessarily equivalent to presence (i.e., function) of apex predators (Ordiz et al. 2013). In terms of conservation goals, caution should be used when applying concepts like umbrella species, indicator species, or ecosystem engineer to large carnivores, particularly generalist predators such as bears and wolves. It is important to recognize the ability of large carnivores to tolerate human activity, exploit anthropogenic food resources, and to coexist with humans in the absence of a natural prey base.

3.5.1 Absence of Natural Prey

In many systems with gray wolves and Eurasian lynx, abundant roe deer, red deer, and wild boar are often observed as primary natural prey base. The two deer species are likely absent from Sarıkamış Forest system due to poor quality habitat and hunting pressure. Red deer are locally extinct and roe deer were recorded by camera traps during 2 survey years, but are functionally extinct. Our research group has not had any sightings or reports of red deer during our field work in Sarıkamış Forest since 2004. Wild boar are present, but in low densities, likely due to direct persecution from farmers that consider them a major agricultural pest (Chynoweth et al. 2016). Scat surveys conducted by the authors in forest patches north of the study area reveal presence of roe deer (Chynoweth, unpublished data), but any ingress of deer from northern forests will be met with hyperabundance of large carnivores and high levels of human activity, neither of which are conducive to recolonization.

The absence of large herbivores in Sarıkamış Forest supports the concept of the empty forest (Redford 1992), where a forest appears intact with full-grown trees, but large mammals are conspicuously absent. Sarıkamış Forest is a monotypic forest of Scots pine; intensive livestock grazing results in an intact canopy and reduction of understory vegetation to grasses and forbs (Zamora et al. 2001). This prevents regeneration of important browse species for native ungulates. Combined with intense human activity and illegal hunting, Sarıkamış Forest in its current unmanaged state may not contain the necessary resources to support red deer or roe deer.

Wild boar, European hare, and red squirrels were detected by our camera traps and represent a small natural prey base for large carnivores, including wolves (Capitani et al. 2016). Wild boar represent a food resource for wolves in many other study areas (Imbert et al. 2016), but occupancy estimates for Sarıkamış are somewhat low, suggesting that wild boar density is low. Low occupancy estimates for European hare and red squirrels are likely slightly biased, due to the small range size and behavior of these species. Nonetheless, our occupancy estimates suggest a deficiency and lack of diversity of natural prey, likely unable to support the hyperabundance of large carnivores in the system.

3.5.2 Hyperabundance of Large Carnivores

Hyperabundance of large carnivores in Sarıkamış Forest is possible due to two main factors. These are the existence of several predictable anthropogenic food sources available on the landscape, mainly garbage (Cozzi et al. 2016) and livestock (Capitani et al. 2016), and the presence of a large (albeit heavily degraded) forested area as a daytime refuge for wildlife. While humans are heavily utilizing forest areas, coexistence with large carnivores is possible due to complementary diel patterns of activity (Figure 3.4). Other factors influencing carnivore abundance may be species-specific.

The large municipal garbage dump has a clear and well-documented effect on the high density of bears in Sarıkamış Forest (Cozzi et al. 2016). Authors routinely observe >10 bears (maximum observed = 33) at the garbage dump during a single night-time visit, with increased numbers during hyperphagia periods prior to bears' hibernation. Impacts of open garbage dumps on bears are well understood, and include food-conditioning and often, increased reproductive rates (Stringham 1989), both of which increase the potential for human-wildlife conflict. As these outcomes illustrate, access to human food sources greatly increases the likelihood of problem bears (Gunther 1994, Huber et al. 2007).

The apparent high density of gray wolves in the study area could be a result of multiple factors. Persecution and limited natural prey base has led to decreased pack size and increased number of packs in the study area. Packs in Sarıkamış Forest typically consist solely of a breeding pair, and solitary wolves are common. While wolves are routinely observed at the open garbage dump, this is limited to a single wolf pack with an overlapping territory (pers obs). The variety of predictable anthropogenic food resources in the area has likely resulted in individual level niche specialization (intraspecies variation) within wolf populations and the ability of wolves to subsist on a diversity of prey, including small mammals (Layman et al. 2015, Newsome et al. 2015a, 2016).

The Eurasian lynx represents the only obligate carnivore and is likely surviving on small mammals (e.g., European hare and red squirrels). Sarıkamış Forest does contain a breeding population of lynx, most probably the subspecies *Lynx lynx dinniki* (Chynoweth et al. 2015). However, effective population size is likely low and this species may be at a tipping point. Using coat pattern to identify individuals, we have observed a maximum of 5 individuals in any given year. Given the high densities of sympatric carnivore species, lynx may be experiencing interspecific competition for natural prey with the gray wolf, as well as through competition and kleptoparasitism with brown bears (Krofel and Jerina 2016).

3.5.3 Effectiveness of Sarıkamış Allahuekber Mountains National Park

Due to complications of sampling, we were not able to detect any difference between occupancy estimates within and outside the boundaries of SAMNP. However, our anecdotal evidence suggests that this national park offers little to no protection for mammal communities in the region. An important cultural memorial, SAMNP was designated in 2004 because of historical significance; during the Battle of Sarıkamış in World War I, over 60,000 Turkish troops died due to harsh winter weather in the Allahuekber Mountains. The park boundaries include vast expanses of agricultural land and habitat unsuitable for large carnivores. Several villages, a large hydroelectric project, and communal grazing lands lie within the park. The apparent lack of restrictions and absence of enforcement enable people from nearby villages to easily harvest forest products (timber, food, etc.).

Because SAMNP was designated for cultural and not environmental reasons, park administration has not effectively taken wildlife management into account. As a result, this National Park cannot claim to function as a protected area for biodiversity and should instead be considered a paper park (Dudley and Stolton 1999) in terms of biodiversity conservation. Our anecdotal evidence of similar or possible lower levels of biodiversity within national park boundaries compared to forested areas outside the park boundaries supports our field observations and bolsters the argument for increasing protected area in larger forest patches within the region.

3.6 Conclusion

This work demonstrates an alternative stable state of large carnivore occurrence, a state defined by human activity and anthropogenic food sources. Our results reveal, for the first time to our knowledge, that generalist predators are able to survive in the absence of natural prey. The hyperabundance of large carnivores may have far-reaching impacts throughout the ecosystem, including increased human-wildlife conflict and, thus, a barrier to achieving conservation goals.

Moving forward, a logical solution may be to increase the extent of the protected area; however, given the highly degraded habitat and pervasiveness of human activity, this may generate controversy due to uneven distribution of benefits that a protected area can provide (Brockington and Wilkie 2015). Eastern Turkey in general and Sarıkamış specifically are regions where people are reliant on natural resources for food, fuel, and grazing lands. Specific strategies for our study site may include intentional rewilding of this forest fragment with species known to naturally occur in the region, such as roe deer and red deer. As such, this study area may provide an opportunity to move the science of rewilding and relocation forward through hypothesis testing and science-based monitoring of the rewilding concept (Seddon et al. 2014, Svenning et al. 2016). These areas of high human activity can constitute experimental plots to test novel hypotheses related to adaptive management. We can try various approaches in Sarıkamış to learn what is best. This approach may be a prerequisite for large carnivore persistence in human-dominated landscapes.

3.7 References

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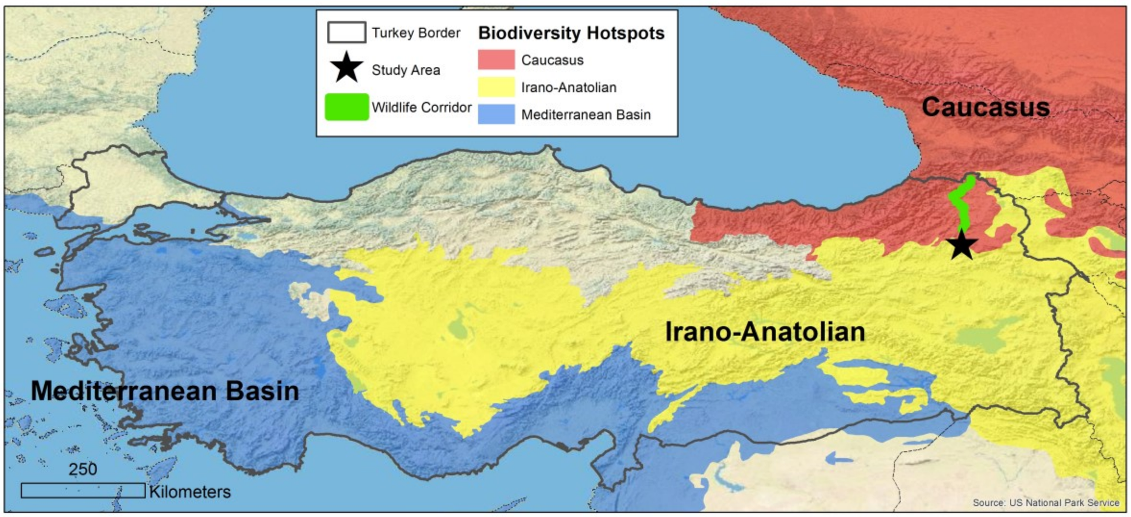

Figure 3.1. The location of Sarıkamış-Allahuekber Mountains National Park and Turkey's first wildlife corridor at the intersection of two global biodiversity hotspots. Turkey is the only country in the world for which >80% is covered by three separate global biodiversity hotspots.

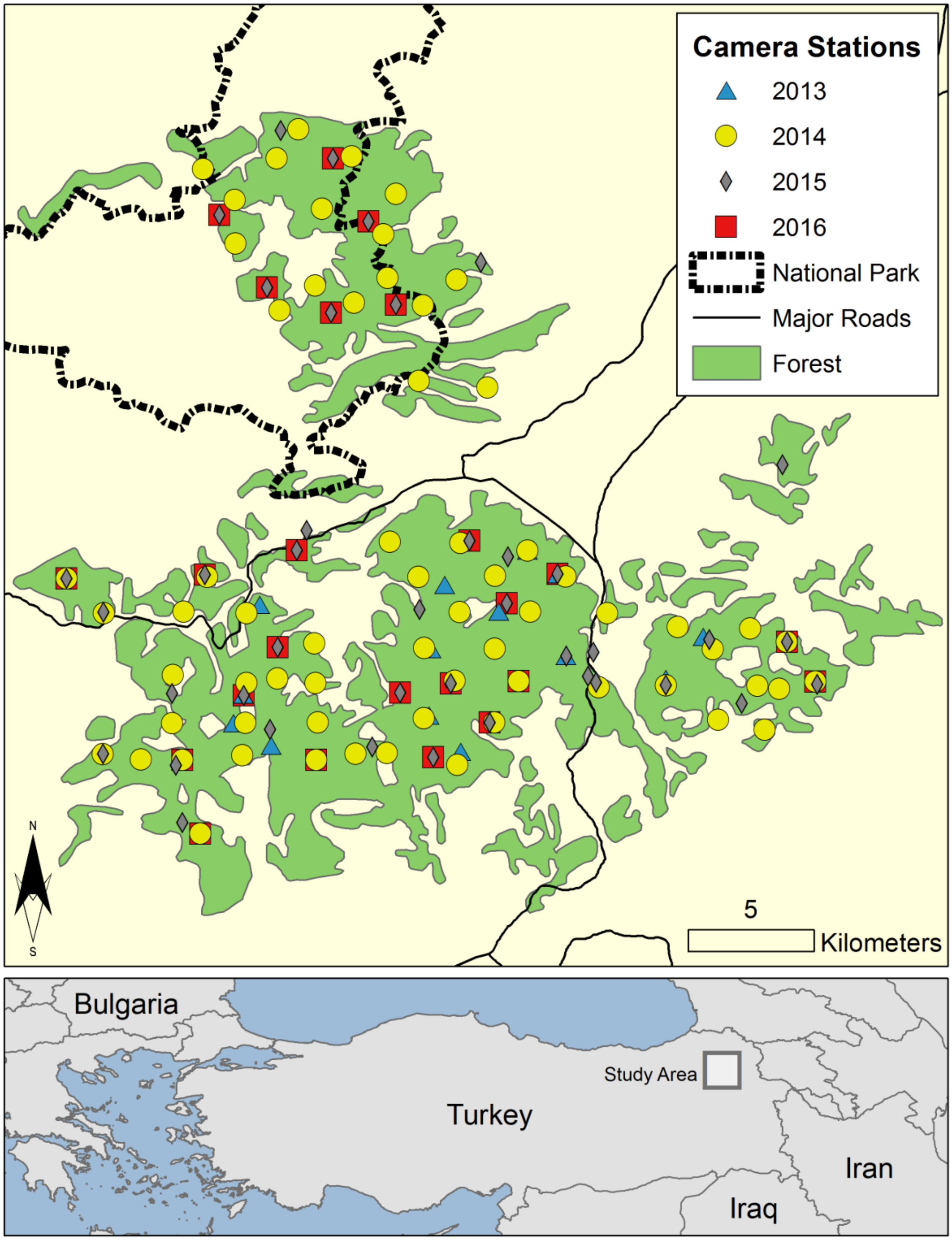

Figure 3.2. Our study area on the border of Kars/Erzurum provinces in eastern Turkey including Sarıkamış-Allahuekber Mountains National Park, surrounding human settlements and camera trap stations for all survey years.

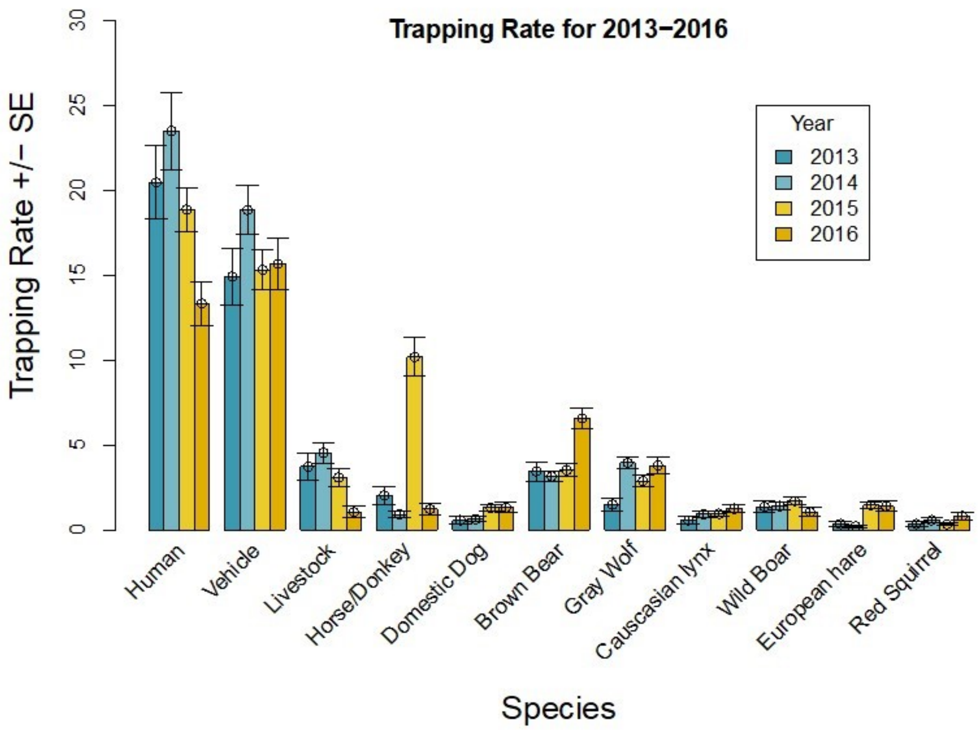

Figure 3.3. Trapping rate of all species captured every year during a camera-trapping survey conducted 2013-2016 in Sarıkamış forest, eastern Turkey. Species not captured during all years are not included, see Table 3.1 for a full species list.

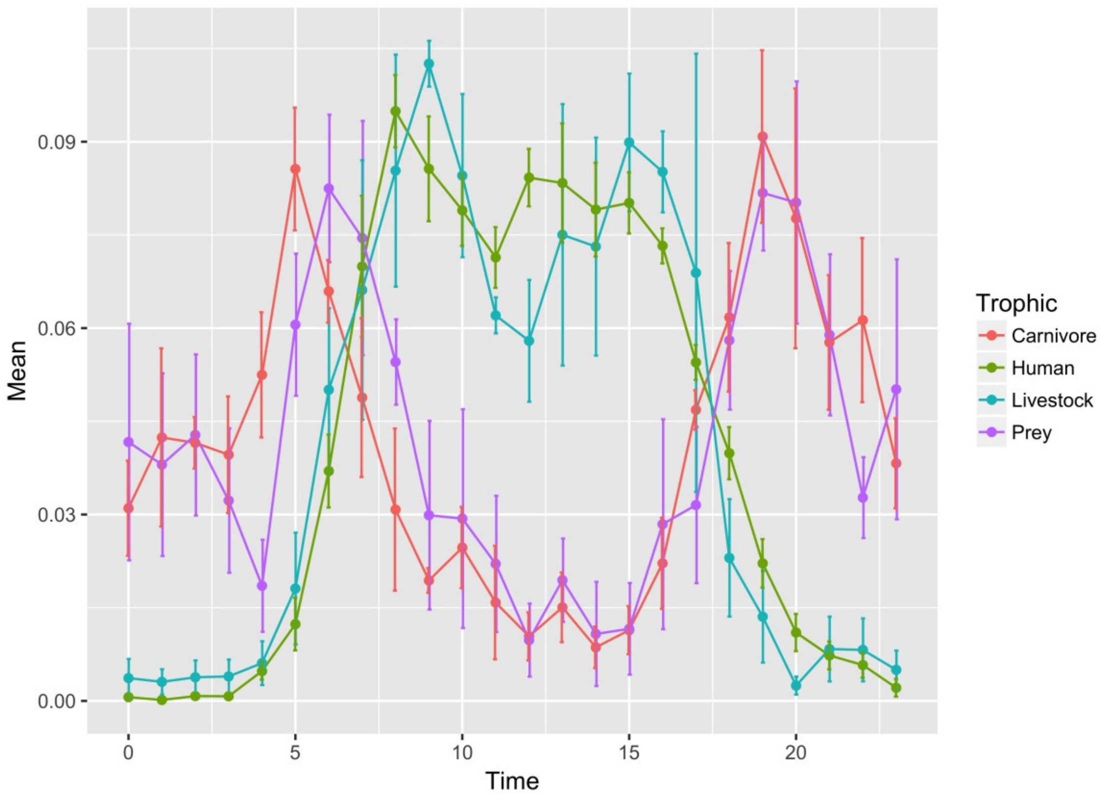

Figure 3.4. Activity patterns of large carnivores, natural prey species, humans, and livestock during a camera-trapping survey conducted 2013-2016 in Sarıkamış forest, eastern Turkey.

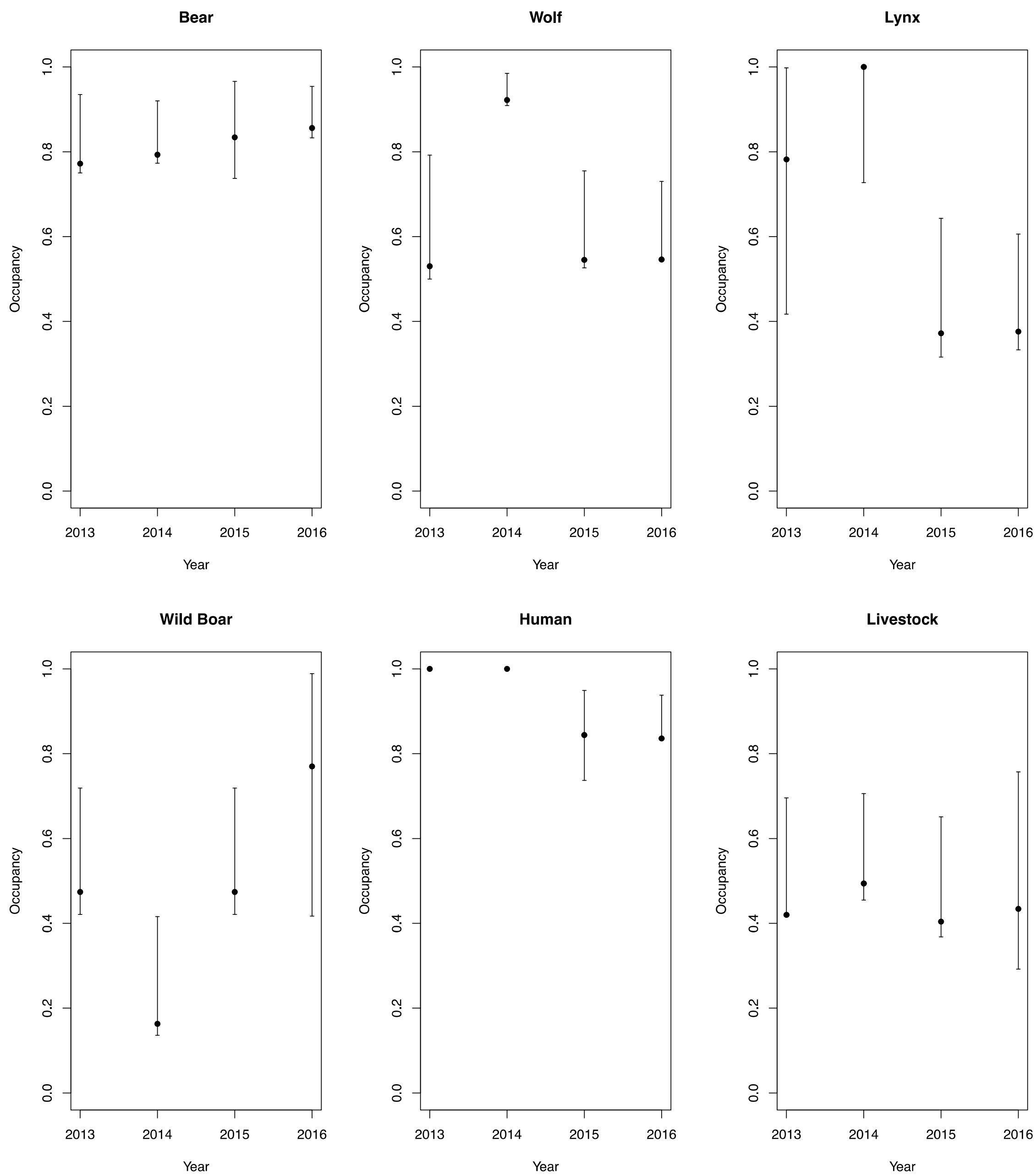

Figure 3.5. Single-species single-season occupancy estimates with 95% confidence intervals by year for a camera-trapping survey conducted 2013-2016 in Sarıkamış forest, eastern Turkey. Occupancy models for humans in 2013 and 2014 did not converge, resulting in an occupancy estimate of 1 with no associated error.

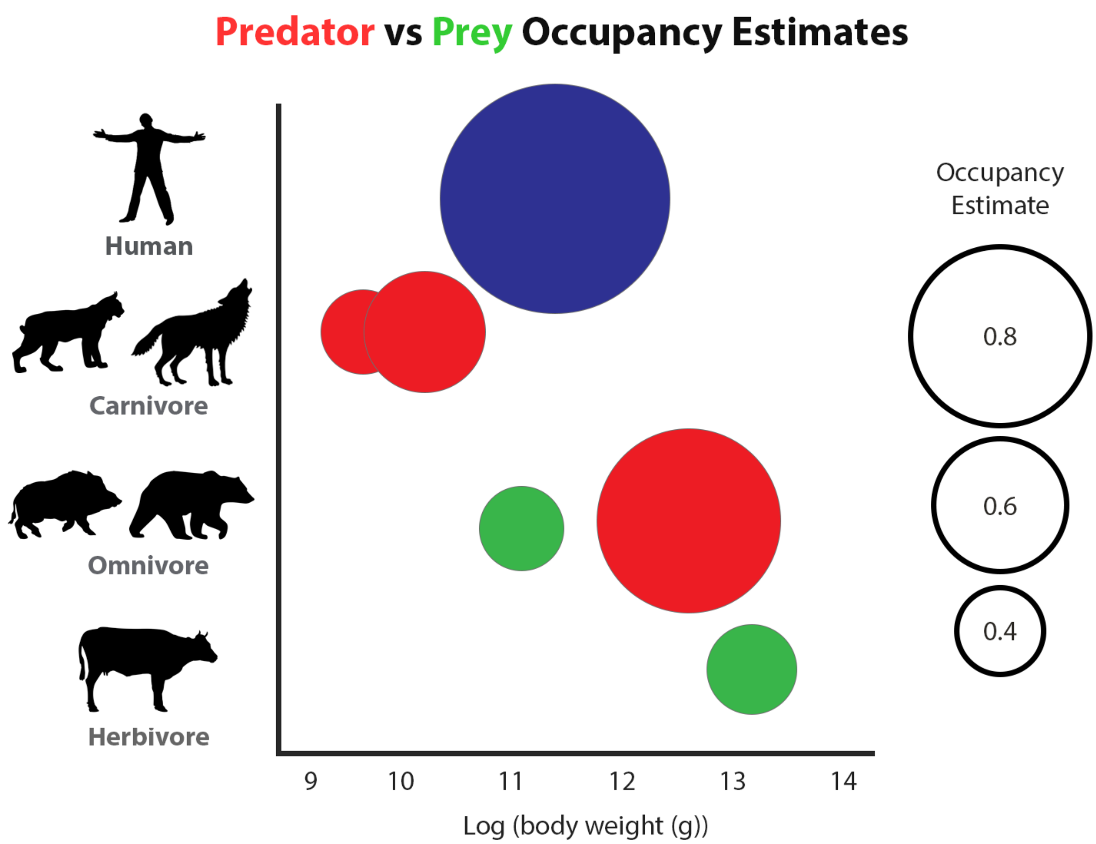

Figure 3.6. Representative mammal community structure for a camera-trapping survey conducted during 2013-2016 in Sarıkamış forest, eastern Turkey. Figure shows the distribution of species along two functional traits: body size (expressed on a log scale) and trophic category. Each circle in the figure represents a species in functional space, with the size of the circle proportional to the estimated occupancy.

Table 3.1. Wild mammal species documented in Sarıkamış forest, eastern Turkey camera-trapping survey conducted 2004-2016 in Sarıkamış forest.

Order	**Genus**	**Species**	**Sub species**	**Common Name**
Artiodactyla	*Capreolus*	*capreolus*		roe deer
Artiodactyla	*Sus*	*scrofa*		wild boar
Carnivora	*Lynx*	*lynx*	*Dinniki*	Caucasian lynx
Carnivora	*Ursus*	*arctos*		Eurasian brown bear
Carnivora	*Meles*	*meles*		European badger
Carnivora	*Canis*	*lupus*		gray wolf
Carnivora	*Vulpes*	*vulpes*		red fox
Carnivora	*Martes*	*foina*		stone marten
Carnivora	*Felis*	*sylvestris*		wildcat
Erinaceomorpha	*Erinaceus*	*concolor*		southern white-breasted hedgehog
Lagomorpha	*Lepus*	*europaeus*		European hare
Rodentia	*Sciurus*	*vulgaris*		red squirrel
Rodentia	*Chionomys*	*nivalis*		snow vole
Rodentia	*Allactaga*	*williamsi*		Williams jerboa
Mammal carcasses discovered in Sarıkamış forest by authors				
Carnivora	*Lutra*	*lutra*		Eurasian otter
Carnivora	*Vormela*	*peregusna*		marbled polecat

Table 3.2. Camera trapping effort in Sarıkamış forest, eastern Turkey conducted 2004-2016 in Sarıkamış forest.

	Pilot Study (2004-2012)	2013	2014	2015	2016
Camera trapping days	1652	1365	3917	3832	1965
Mean trapping days per camera	-	112	76	127	81
Successful stations	-	12	51	27	24
Cameras stolen	-	1	9	7	6

Table 3.3. Modeled occupancy and detection probabilities for 2013 camera trapping effort in Sarıkamış forest, eastern Turkey. Modeling criteria A is naïve occupancy estimate >0.1, modeling criteria B is modeled detection probability 0.1.

Species	No. of Events	Occupancy					Detection Probability				Modeling Criteria	
		Naïve Estimate	Modeled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Modeled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	A	B
Brown bear	45	0.75	0.772	0.13	0.75	0.935	0.17	0.03	0.119	0.238		
Livestock	46	0.417	0.42	0.143	0.417	0.696	0.23	0.044	0.155	0.327		
Caucasian lynx	8	0.417	0.782	0.44	0.417	0.998	0.039	0.026	0.011	0.135		
Eurasian red squirrel	5	0.25	0.357	0.215	0.25	0.778	0.061	0.039	0.017	0.197		
European hare	5	0.333	0.858	0.73	0.333	1	0.026	0.024	0.004	0.151		
Gray wolf	21	0.5	0.53	0.155	0.5	0.792	0.141	0.035	0.085	0.224		
human	278	1	1	0	1	1	1	0	1	1		
Wild boar	20	0.421	0.474	0.026	0.421	0.719	0.066	0.017	0.04	0.107		

Table 3.4. Modeled occupancy and detection probabilities for 2014 camera trapping effort in Sarıkamış forest, eastern Turkey. Modeling criteria A is naïve occupancy estimate >0.1, modeling criteria B is modeled detection probability 0.1.

Species	No. of Events	Occupancy					Detection Probability				Modeling Criteria	
		Naïve Estimate	Modelled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Modelled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	A	B
Brown bear	116	0.773	0.793	0.092	0.773	0.92	0.18	0.024	0.138	0.231		
Livestock	146	0.455	0.494	0.114	0.455	0.706	0.169	0.029	0.12	0.233		
Caucasian lynx	33	0.727	1	0.017	0.727	1	0.165	0.013	0.044	0.195		
Eurasian red squirrel	19	0.273	0.311	0.109	0.273	0.551	0.13	0.034	0.076	0.213		
European hare	8	0.136	0.174	0.1	0.136	0.45	0.089	0.044	0.032	0.223		
Gray wolf	142	0.909	0.922	0.063	0.909	0.985	0.207	0.022	0.166	0.254		
human	1451	1	1	0	1	1	1	0	1	1		
Wild boar	58	0.136	0.163	0.026	0.136	0.163	0.039	0.018	0.015	0.095		

Table 3.5. Modeled occupancy and detection probabilities for 2015 camera trapping effort in Sarıkamış forest, eastern Turkey. Modeling criteria A is naïve occupancy estimate >0.1, modeling criteria B is modeled detection probability 0.1.

Species	No. of Events	Occupancy					Detection Probability				Modeling Criteria	
		Naïve Estimate	Modelled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Modelled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	A	B
Brown bear	130	0.737	0.834	0.122	0.737	0.966	0.114	0.022	0.078	0.164		
Livestock	95	0.368	0.404	0.124	0.368	0.651	0.124	0.031	0.074	0.199		
Caucasian lynx	34	0.316	0.372	0.133	0.316	0.643	0.197	0.032	0.051	0.179		
Eurasian red squirrel	12	0.158	0.229	0.145	0.158	0.597	0.061	0.039	0.017	0.196		
European hare	53	0.211	0.215	0.095	0.211	0.453	0.194	0.047	0.118	0.302		
Gray wolf	103	0.526	0.545	0.119	0.526	0.755	0.162	0.029	0.114	0.227		
human	528	0.842	0.844	0.084	0.765	0.949	0.288	0.026	0.239	0.342		
Wild boar	63	0.421	0.474	0.133	0.421	0.719	0.109	0.029	0.064	0.18		

Table 3.6. Modeled occupancy and detection probabilities for 2016 camera trapping effort in Sarıkamış forest, eastern Turkey. Modeling criteria A is naïve occupancy estimate >0.1, modeling criteria B is modeled detection probability 0.1.

Species	No. of Events	Occupancy					Detection Probability				Modeling Criteria	
		Naïve Estimate	Modelled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Modelled Estimate	Standard Error	Lower 95% CI	Upper 95% CI	A	B
Brown bear	128	0.833	0.856	0.079	0.833	0.954	0.215	0.026	0.169	0.269		
Livestock	15	0.292	0.434	0.175	0.292	0.757	0.074	0.033	0.03	0.17		
Caucasian lynx	25	0.333	0.376	0.112	0.333	0.606	0.141	0.037	0.083	0.23		
Eurasian red squirrel	16	0.25	0.424	0.205	0.25	0.793	0.061	0.032	0.021	0.163		
European hare	28	0.417	0.475	0.121	0.417	0.7	0.092	0.033	0.08	0.211		
Gray wolf	74	0.542	0.546	0.103	0.542	0.73	0.278	0.034	0.216	0.349		
human	252	0.833	0.836	0.076	0.833	0.938	0.328	0.028	0.275	0.385		
Wild boar	21	0.417	0.77	0.302	0.417	0.989	0.053	0.024	0.021	0.126		

CHAPTER 4

MOVEMENT ECOLOGY AND RESOURCE SELECTION OF THREE LARGE CARNIVORES IN A PREY-DEFICIENT, HIGHLY DEGRADED ECOSYSTEM

4.1 Abstract

Conservation and management of wildlife populations is becoming increasingly complex in a world where novel and hybrid ecosystems are emerging from human-dominated landscapes. As human impact intensifies, it is important to consider movement and resource selection of wildlife to inform sustainable management decisions in highly-modified landscapes. Resource selection models can identify important habitat for species and guide conservation efforts to increase protected area coverage. To understand how large carnivores are able to coexist with people in heavily modified landscapes, we deployed GPS collars on 16 adult Eurasian brown bears, 7 gray wolves, and 2 Caucasian lynx in eastern Turkey to study their movement ecology. We developed species-specific seasonal resource selection functions to identify high-priority habitat in the area, and to identify suitable habitat for increasing protected area coverage. All 3 species' habitat selection varied between seasons. Brown bears selected for areas closer to paved roads, further from human settlements, and located on steeper slopes throughout the year. During spring, bears preferred lower elevations and more open areas, and during summer

and fall, bears preferred higher elevations. Wolves selected for forested areas, areas closer to roads, farther from villages, and steeper slopes throughout the year. Wolves selected for higher elevations during summer and lower elevations during winter. Lynx selected for steeper slopes throughout the year. During summer, lynx selected for forested areas, areas farther from villages, and higher elevations, while during winter, they selected for areas slightly closer to forests. Using predictive maps, we identified important habitat in the area for all three species and propose a new protected area designation in the region.

4.2 Introduction

Human activity has become the driving ecological force on our planet, shaping ecosystem structure and function in the new geological epoch, the Anthropocene (Zalasiewicz et al. 2008). The impact of human domination can be detected in geological, chemical, and biological signals, but few are as daunting as what is known as the sixth mass extinction (Barnosky et al. 2011). Part of this process is global defaunation, particularly of large mammals (Dirzo et al. 2014). Large mammals are highly vulnerable to extirpation by humans due to their large size, slow reproductive rates, and vast habitat requirements (Cardillo 2005). Within this group, large carnivores represent a distinct faction, particularly at risk because of their natural rarity and risk of persecution from humans. Nonetheless, some large carnivore species are able to alter their behavior to exploit new resources in a changing environment.

Increasingly, wilderness and natural areas are surrounded by a matrix of highly altered, human-modified landscapes (Hobbs et al. 2014). This juxtaposition of habitat can result in a combination of suitable habitat with an abundance of anthropogenic food resources for generalist predators. Anthropogenic food resources result in behavioral changes in predators (Cozzi et al. 2016), which are likely to reduce the effect of trophic cascades (Newsome et al. 2015). A consequence of becoming habituated to human food sources is increased human-wildlife conflict, which may include vehicle collisions and direct persecution via poisoning or illegal hunting. However, human-altered landscapes may also provide benefits, such as highly productive agricultural areas or increased prey availability through livestock presence. This is a new avenue of research in large carnivore ecology, supported by recent studies suggesting limited scientific support for popular concepts in carnivore ecology such as trophic cascades (Haswell et al. 2017, Kuijper et al. 2016, Allen et al. 2017). In our changing world, there is a critical need for more data on large carnivore movement in human-dominated landscapes.

Resource selection functions (RSFs) can serve several purposes when examining large carnivore ecology in human-dominated landscapes. Gaining an understanding of how these animals use resources can help scientists and managers understand how human-carnivore coexistence can occur and what conditions must exist for its facilitation (Carter et al. 2012, Oriol-Cotterill et al. 2015). RSFs can also identify patterns in the habitat selection of threatened species to enable their persistence (Dellinger et al. 2013), as well as to identify potential corridors for wide-ranging species (Chetkiewicz and Boyce 2009).

We used RSFs to investigate habitat selection and movement patterns of three large carnivore species in eastern Turkey, in a fragmented forest within a human-dominated landscape surrounding Sarıkamış-Allahuekber Mountains National Park (hereafter

Sarıkamış Forest). At the intersection of the Caucasus and Iran-Anatolian global biodiversity hotspots, wildlife biology and mammal ecology in this region are mostly unstudied. Similar to many other parts of the developing world, Turkey's biodiversity is globally important and increasingly threatened (Şekercioğlu et al. 2011). We were interested in understanding how Eurasian brown bears (*Ursus arctos arctos*), gray wolves (*Canis lupus lupus*), and Caucasian (Eurasian) lynx (*Lynx lynx dinniki*) are able to persist in a human-dominated landscape largely devoid of natural prey species (Chynoweth et al. in prep). By taking a multispecies approach, we hope that results from this study will help guide conservation efforts for the region, using these three landscape carnivores as umbrella species to increase protected area coverage in the region (Lambeck 1997).

Our previous work in the same system documented a unique mammal community structure characterized by the hyperabundance of these three large carnivore species (Chynoweth et al. in prep), an absence of natural prey, and synanthropic behavior of bears (Cozzi et al. 2016) and wolves (Capitani et al. 2016). Importantly, using the data also presented here, we identified two distinct life history traits coexisting within this population of bears: bears that regularly visited the dump and remained sedentary year-round and bears that never visited the dump and migrated (see Cozzi et al. 2016 for details). Based on these results and the goal to inform conservation of large carnivores in Sarıkamış Forest specifically, we used in our analysis only the bears that did not visit the dump. We hypothesized that large carnivores in Sarıkamış Forest would show seasonal variation in habitat selection related to snow cover and associated human presence in the landscape. We hypothesized that all three species would select for steeper slopes and for areas closer to forests. We also hypothesized that wolves and bears would select for areas closer to villages, while lynx, as an obligate carnivore, would select for forested areas and areas away from human activity.

4.3 Methods

4.3.1 Study Area (from section 3.3.1)

Our study was carried out on the Kars-Ardahan high plateau in northeastern Turkey, at the intersection of Caucasus and Irano-Anatolian global biodiversity hotspots. The area (c. 550 km^2; 40°20'N 42°35'E) ranges between 1900 and 3120 m asl and is composed of fragmented forest in a matrix of agricultural and rangelands. The city of Sarıkamış (population: c. 18,000) is located in the center of the study area and on one of the two paved roads that bisect the forested area. Forest cover consists almost exclusively of Scots pine (*Pinus sylvestris* Linnaeus, 1753), while understory vegetation is scarce, with consequent scarcity of food resources for browsers. Sarıkamış-Allahuekber Mountains National Park (hereafter SAMNP; Figure 4.1) boundaries cover a total area of 225.1 sq. km., but only include 49.69 sq. km. of forest. Therefore, SAMNP is only comprised of 22.07% forest cover. Total forest cover in the region includes 328.38 sq. km. including a large expanse of forest south of the national park (248.15 sq. km.). These patches of forest represent the southernmost significant forest patch in the region extending south from the extensive forests in the Black Sea Region of Turkey.

Human activity in the forest is extensive in both time and space, limited only by harsh winter temperatures, and consists primarily of livestock grazing, harvest of forest products (e.g., fruits, pine cones, mushrooms), and legal and illegal timber extraction. Livestock is abundant in the region with cattle (Bos taurus Linnaeus, 1758), sheep (Ovis aries Linnaeus, 1758), and goats (Capra hircus Linnaeus, 1758) freely roaming rangelands from April to November (Capitani et al. 2016). About 851,445 livestock heads have been registered in the Kars province in 2012 (Ministry of Food, Agriculture and Livestock, Republic of Turkey). A notable feature on the landscape is an unfenced municipal garbage dump 3 km west of Sarıkamıs city. The dump represents a predictable anthropogenic food source, and bears, wolves, and wild boar visit the dump regularly at night (pers. obs.). A portion of the bear population has altered life history strategies to regularly use the dump, while other bears never visit the dump (Cozzi et al. 2016).

4.3.2 Animal Capture

From 2012-2014, we captured bears, wolves, and lynx of a variety of ages and fitted satellite transmitters to them. An experienced carnivore biologist from Zagreb University and a wildlife veterinarian from local Kafkas University were present for the captures and the necessary permits were obtained from Turkey’s Ministry of Forestry and Water Affairs. Data were added to the online Movebank database and are available upon request.

4.3.2.1 Bears

We captured 18 males and 10 females using Aldrich snares in opposing entrances to European-style cubbies baited with fresh sheep carcasses. GPS/GSM radio collars (GPS Plus; Vectronic Aerospace GmbH, Berlin, Germany) were attached to immobilized bears after aging and health assessment. Bears were monitored for a mean duration of 296 days (range: 125–590 days). GPS acquisition rate was >90% for all but one individual; only location fixes with a three-dimensional fix and low Positional Dilution of Position value (PDOP < 10) were included in final datasets for analysis. Data recorded during hibernation were not included in any analysis.

4.3.2.2 Wolves

We captured 7 male and 4 female wolves using padded leg hold traps cross-baited with wolf scat, wolf urine and/or rotten liver. GPS/GSM radio collars (GPS Plus; Vectronic Aerospace GmbH, Berlin, Germany) were attached to immobilized wolves after aging and health assessment. Collars were programmed to log a GPS location every 6 hours for 1 year. Wolves were monitored for a mean duration of 307 days (range: 167–365 days). GPS acquisition rate was >90% for all individuals; only location fixes with a three-dimensional fix and low Positional Dilution of Position value (PDOP < 10) were included in final datasets for analysis.

4.3.2.3 Lynx

We captured 2 adult male lynx using live box traps custom designed in Sarıkamış. GPS/GSM radio collars (GPS Plus; Vectronic Aerospace GmbH, Berlin, Germany) were attached to immobilized lynx after aging and health assessment. Collars were programmed to log a GPS location every 4 hours for 1 year. The 2 individual lynx were monitored for 342 and 283 days. GPS acquisition rate was >90% for all individuals; only location fixes with a three-dimensional fix and low Positional Dilution of Position value (PDOP < 10) were included in final datasets for analysis.

4.3.3 Home Ranges and Utilization Distributions

Utilization distribution (UD) and home range area estimates were calculated using adaptive-kernel density estimators with *adehabitat* package in R (Calenge 2006). Home range estimates were generated with an ad hoc smoothing parameter using the smallest increment of the reference bandwidth (href) that provided a contiguous 95% kernel home range (i.e., h = 0.5 × href, 0.6 × href,... href–J. Kie, pers. comm.). The number of points used to generate annual utilization distributions ranged from 674 to 16,497, providing robust estimates of kernel density. Home range estimates provide a 95% utilization distribution and a 95% isopleth home range for individual animals at a 30 × 30 m resolution.

4.3.4 Environmental Data

We compiled existing environmental data from our study area in a Geographic Information System (GIS). To test the effect of landscape features on animal movement and habitat selection, we created six geo-referenced raster layers that included distance to the nearest village, distance to the nearest paved road, distance to forest cover, altitude, slope, and aspect (Table 4.1). Each layer fully covered the extended study area and was characterized by a cell size of 30 x 30 m. All six variables were retained for further analyses since we did not detect strong correlations ($r < 0.37$ for any pair).

We obtained a land cover map from the Turkey's Ministry of Forestry and Water Affairs at a resolution of 1:25,000, which included two major land cover types: forest and open land, and calculated the distance between each raster centroids and the closest forest patch, the mean distance being 6,056 m (range: 0.1 – 42,727 m). We acquired topographic information on altitude (mean: 1933 m, range: 881 – 3132 m), slope (mean: 16 degrees, range: 0 – 75 degrees), and aspect (mean: 178 degrees, range: 0 – 360 degrees) from an ASTER Global Digital Elevation Map (http://reverb.echo.nasa.gov). We calculated the distance between each raster centroids and the closest road, the mean distance being 5,643 m (range: 0.1 – 26,499 m). Because this study was located in a rural area with very low traffic, we only considered paved national and regional roads (Turkey's Ministry of Forestry and Water Affairs). Finally, we obtained a GIS layer from Turkey's Ministry of Forestry and Water Affairs with the locations of 356 villages (mean density: 1 village/20 km^2). Villages were relatively evenly distributed throughout the entire study area with mean distance between raster centroids and villages equal to 2,502 m (range: 0.5 – 11,046 m).

4.3.5 Model Development, Selection, and Predictions

We analyzed bear, wolf, and lynx resource selection based on Johnson (1980) "third order selection," or how an animal uses habitat components within its home range. We used a resource selection function approach with a use-availability design (Manly et al. 2002) to examine the relationship between resource use and habitat covariates. Thus, we determined used and available habitat within each animal's 95% kernel home range. Recorded GPS locations were considered to be used locations, because we knew that the animal was present at that location at a given time. Available habitat was determined by systematically sampling habitat at 100 m intervals within each animal's 95% kernel home range. This resulted in a database with all used and available points for each individual of each species with all associated covariate data with a binary response variable of use.

Based on our previous work and environmental conditions in the area, our aim was to understand how these three species select for resources in a human-dominated, prey-deficient system.

To reflect seasonal resource selection among species, we partitioned location data by season from approximate dates of snow cover and food availability, based on authors' multiyear experience and previous work in the study area (Capitani et al. 2016, Cozzi et al. 2016). Wolf and lynx data were partitioned into two seasons: winter (Nov 16 – April 15) and nonwinter (April 16 – Nov 15). Brown bear data were partitioned into three seasons: spring (end hibernation – May 31), summer (June 1 – Aug 31), and fall (Sept 1 – begin hibernation). All bear migration data identified in Cozzi et al. (2016) were excluded from analysis in this manuscript, because bears were moving through large expanses of open habitat to very different forest types; therefore including these points would not inform conservation efforts specific to Sarıkamış Forest. RSFs were created by comparing seasonal bear, wolf, and lynx locations to available location within an individual's annual home range.

All covariate data were standardized to enable comparison between the effects of covariates on habitat selection and to aid in model convergence. Individual animals were treated as a random effect to account for interindividual variability. We used generalized linear models (GLMs) with the *lme4* package in R and assessed the variance inflation factors (VIF) with the *usdm* package in R (threshold $|r| > 0.50$). An information theoretic approach for model selection was used to compare models (Burnham and Anderson 2002). We employed backward stepwise selection for final model selection, using the Aikake Information Criterion, adjusted for small sample sizes (AICc) with the

AICcmodavg package (Mazerolle and Mazerolle 2011). To start, all variables were included in every model; then we removed those that were nonsignificant until all variables left were significant at the p =0.05 level. Ninety-five percent confidence intervals were calculated to ensure that each variable was truly significant

Final RSF models were input in ArcGIS 10.3.1 to generate population level probability of use for each species at each 30 m resolution cell across the study area. Probabilities were classified into five quantile bins to represent areas of low – high habitat suitability, which represent categories of increasing habitat selection (Johnson et al. 2006).

To test the accuracy of our final models, we followed a 10-fold cross validation procedure to examine model performance (Boyce et al. 2002). We split data into 10 equal parts (folds) and kept observation (i.e., used and alternative locations) from the same strata in the same fold. We then fit the model to all data except the *i*th fold and calculated parameter estimates (β1,… βn). We used the calculated β parameters to estimate $w(X)$ values for the *i*th fold. We then binned the data based on the deciles of the estimated $w(X)$ values and calculated the spearman correlation coefficient (r_s) between the proportion of used locations in each bin and the mean $w(X)$ value in each bin. All statistical analyses were conducted in R (R Core Team 2016).

4.3.6 Prioritizing Conservation Areas

We used all validated species-specific seasonal models overlaid in ArcGIS to determine the highest suitability habitat for all three species. Relative probability of habitat use was summed across species and seasons and reclassified into four quantile bins, and the highest category bin was used to represent the most suitable habitat for future conservation efforts. Through this subjective conversion, we assumed that areas identified by this method are the highest quality across seasons and species. We converted the re-binned raster surface into polygons using ArcGIS and selected the single largest contiguous polygon of the highest quantile bin in the region and removed all smaller patches of possible area. We then clipped this single polygon by forest cover to identify areas suitable for protected area status given that deforested areas are typically rangeland. Lastly, we bounded these polygons by a minimum convex polygon to identify a contiguous area that includes all forested area with the highest probability of habitat use for all three species.

4.4 Results

We captured 28 bears, 11 wolves, and 3 lynx between 2011 and 2016. Collars were only deployed on adult animals. Equipment failure and mortality (actual and perceived) reduced our sample size to 16 bears, 7 wolves, and 2 lynx. Most animals spent the majority of their time in the main study area (see Cozzi et al. 2016 for an explanation of migratory bear behavior), but notably, two wolves were dispersing individuals and were not retained in the dataset. Mean home ranges for bears were 109 ± 17.67 km^2, while mean home ranges for wolves and lynx were highly variable, 1263.1 ± 786.8 km^2 and 1296.8 ± 917 km^2, respectively, due to small sample size and one wide ranging individual of each species (Table 4.2).

4.4.1 Resource Selection Functions

Bears selected for sites farther from paved roads, closer to human settlements, and steeper slopes during all seasons. During the spring season, bears preferred lower elevations and more open areas, and during the fall season, bears preferred higher elevations (Figure 4.2). Predictive accuracy for seasonal models using withheld model-testing data was variable between seasons (spring; $r^2 = 0.833$ ($p < 0.05$), summer; $r^2 = 0.923$ ($p < 0.001$), autumn; $r^2 = 0.948$ ($p < 0.001$)).

Wolves selected for forested areas, as well as areas closer to roads, farther from villages, and with steeper slopes during all seasons. They selected for higher elevations during the summer season and for lower elevations during the winter season (Figure 4.3). Predictive accuracy for seasonal models using withheld model-testing data was variable between seasons with the winter season model performing poorly (summer; $r^2 = 0.865$ ($p < 0.05$), winter; $r^2 = 0.347$ (n.s.)).

Lynx selected for steeper slopes during all seasons. During the winter season, they selected for areas farther from human settlements, closer to forests, and higher in elevation, while during nonwinter seasons, they selected for areas outside of forests (Figure 4.4). Predictive accuracy for seasonal models using withheld model-testing data was variable between seasons with the winter season model performing poorly (summer; $r^2 = 0.929$ ($p < 0.001$), winter; $r^2 = 0.435$ (n.s.)).

4.4.2 Prioritizing Conservation Areas

All three seasonal RSF models for bears were validated, and summer models for wolves and lynx were validated. By combining all validated seasonal models across species, an area of 161.4 km^2 was identified as the highest quality habitat for bears, wolves, and lynx in the region to prioritize future conservation efforts (Figure 4.8). This area includes 102.6 km^2 of forest and one human settlement and is bisected by a two-lane highway. SAMNP is the only other protected area in the region with 49.7 km^2 total forested area within park boundaries Therefore, protecting this prioritized area would double protected forest (106% increase) and result in protection of 46.4% of the total forest cover in the region.

4.5 Discussion

Our study contributes critical information about brown bear, gray wolf, and Eurasian lynx home ranges and resource selection in an understudied region of the world. Species-specific seasonal resource selection models identify areas in the landscape with high probability of habitat selection at the population level and can be used to identify suitable habitat for a species. There was some variation in model performance between seasons; bear models performed well for all three seasons, while wolf and lynx summer models performed well, and winter models had low (nonsignificant) model validation scores. Poor model performance for winter models is likely related to the wide-ranging behavior of wolves and lynx during this season. Animals are traveling through open landscapes more often and depending on the assignment of data to any of the 10 folds, some strata during winter season have no used or alternative locations in forest. For this season, we caution the interpretation of due to the poor model performance. All validated model outputs were used to identify an area to be targeted for future conservation efforts, with the overall goal to increase protected area in region.

Resource selection by brown bears, gray wolves, and Eurasian lynx varied by season, similar to other studies (Chetkiewicz and Boyce 2009, Latham et al. 2013). Across all three species, elevation had the largest and most varied effect on habitat selection. For wolves and lynx, this is likely related to contrast in human activity patterns between seasons. During the winter, when wolves and lynx are selecting for low elevation areas, harsh weather conditions prevent villagers from accessing the majority of forested area, as well as the vast open rangelands surrounding the forest. Therefore, wolves and lynx can move more freely through low elevation open areas. During the summer season, when wolves and lynx are strongly selecting for high elevation forested areas, human activity is frequent and ubiquitous throughout the forest. Given the lack of natural prey in the area (Chynoweth et al. in prep) and known predation of livestock by wolves (Capitani et al. 2016), these two species are likely forced to travel farther distances in search of prey during the winter season when livestock are in closed, protected pens near villages. This corresponds with anecdotal evidence from villagers who state they frequently see wolves during winter months close to villages preying on dogs and other domestic animals (Chynoweth et al. 2016).

Brown bears also demonstrate strong seasonal patterns related to elevation. During the spring season, the importance of primary productivity is likely driving their selection for lower elevations, based on their reliance on herbaceous vegetation as an omnivore (Rode et al. 2001, Robbins et al. 2004) and on the lack of food resources at higher elevations covered in snow. During the summer season, bears begin to select for higher elevation with selection becoming stronger in the fall, likely related to human activity in the forest and food availability similar to results from wolf and lynx models. Den site selection also impacts selection for high elevation in the fall, as these sites are all located in high elevation, steep, and rugged terrain (Chynoweth, pers obs).

Distance to forest also had a varied effect on RSFs across season and species. Similar to patterns observed in selection for elevation, the strong selection for forest demonstrated by both wolves and lynx in the summer is probably driven by human activity and the importance of forest cover as a refuge from potential persecution. Wolves also selected for forest cover during the winter season. Both lynx individuals rarely left forested areas during the summer season. However, model results for lynx suggested avoidance of forest cover by lynx during the winter season. This is a product of small sample size (n=2) and individual variation in home range and movement patterns. One lynx was completely confined by forest cover in a well-defined home range, while the other lynx had a much less well-defined territory and also took a 3-month foray out into open rangelands during the winter season, wandering over 40 km from the nearest forest and close to Kars city (human population of ~80,000 people). Model validation results for both wolves and lynx was poor for winter seasons, likely a result of this individual variation.

Slope was a significant predictor of habitat selection for all species in all seasons, with positive relationship between slope and probability of use. Field observations by authors suggest that slope may be a proxy for forest quality in Sarıkamış forest due to the heavy grazing that occurs throughout the forest, which has had long-term consequences for forest structure. Steeper areas are more difficult for livestock to access and are therefore less intensely grazed and maintain more understory vegetation than flatter areas.

Our prediction that bears and wolves would prefer areas closer to human settlements was not supported, with both species selecting for areas farther from villages during all seasons. However, the distribution of anthropogenic food sources across the landscape is not well known, with the exception of the large municipal garbage dump located 3 km outside of the city of Sarıkamış. However, through our ongoing fieldwork in the region, we have identified the presence of numerous smaller garbage dumps throughout the area and documented the use of these refuse piles by wolves and bears. Furthermore, the presence of livestock, both live and as carcasses, is ubiquitous in this landscape during nonwinter months and likely plays an important role in the diet of wolves (Capitani et al. 2016) and possibly bears. Our results are not surprising, as wolves have been observed using garbage dumps nightly in Italy (Ciucci et al. 1997), and both black and brown bears are known to use open garbage dumps as a food source (Craighead and Craighead F. C 1972, Rogers et al. 2014).

4.6 Conclusion

Our results are an example of using resource selection functions across multiple species to prioritize conservation efforts in an understudied region of the world in critical need of increased conservation efforts (Sekercioglu et al. 2011, Şekercioğlu et al. 2011). Understanding the behavior of large carnivores in this human-dominated landscape will also elucidate the mechanisms that allow these species to persist in an alternative stable state in a heavily degraded landscape devoid of natural prey (Chynoweth et al. in prep). While the use of anthropogenic resources by carnivores is well documented, these baseline results are a critical contribution to the expanding field of large carnivore ecology and conservation in human-dominated landscapes. However, more work needs to be done to further understand if this could be an example of an ecological trap (Gates and Gysel 1978), evolutionary trap (Schlaepfer et al. 2002), or simply the persistence of these species beyond a tipping point. Regionally, these results are critical to science-based management of individual species and biodiversity. Results will be used to guide wildlife management, establish new protected areas, and provide solutions to existing human-wildlife conflict.

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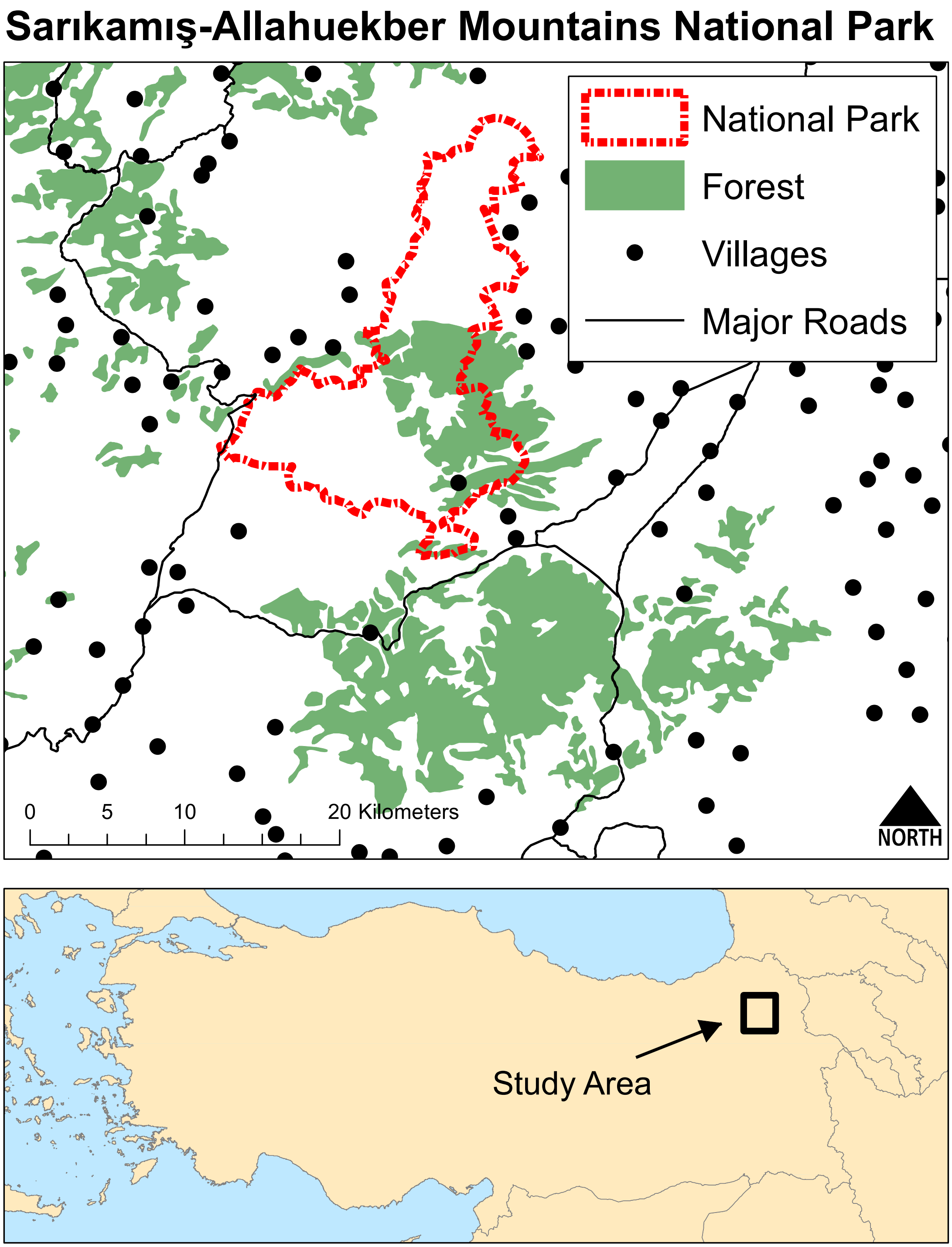

Figure 4.1. Location of Sarıkamış-Allahuekber Mountains National Park and surrounding forest in eastern Turkey.

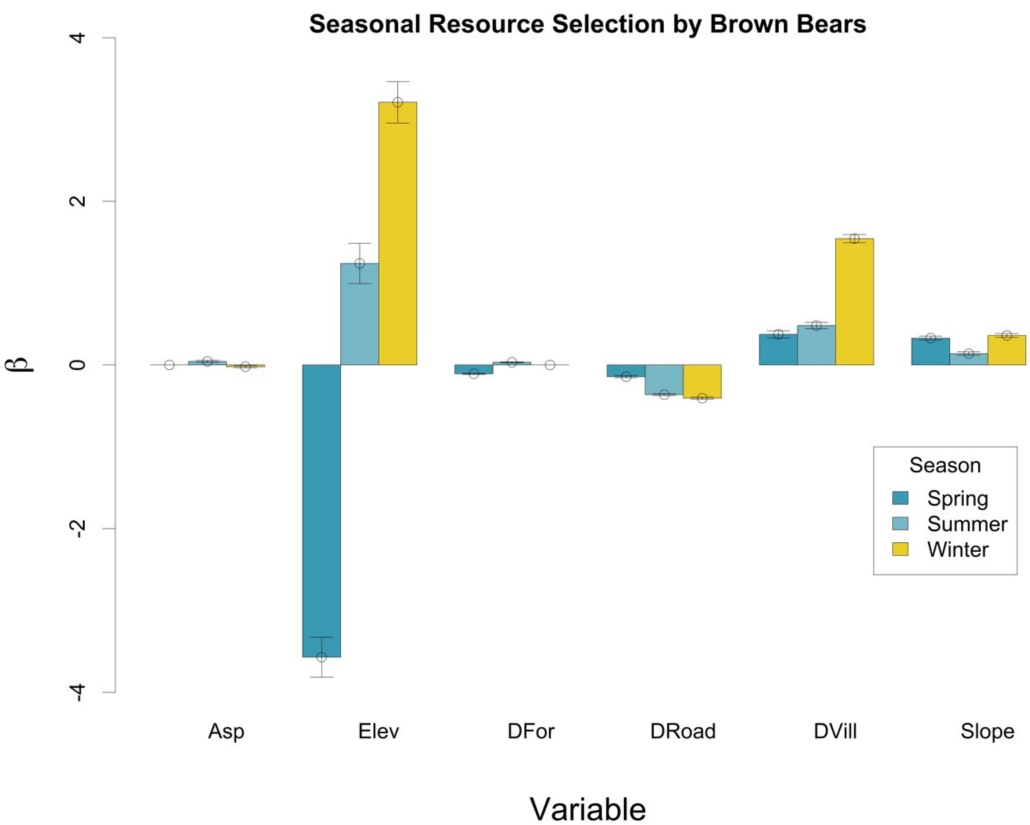

Figure 4.2. Seasonal resource selection by bears in Sarıkamış forest, eastern Turkey. See Table 4.1 for descriptions of variables.

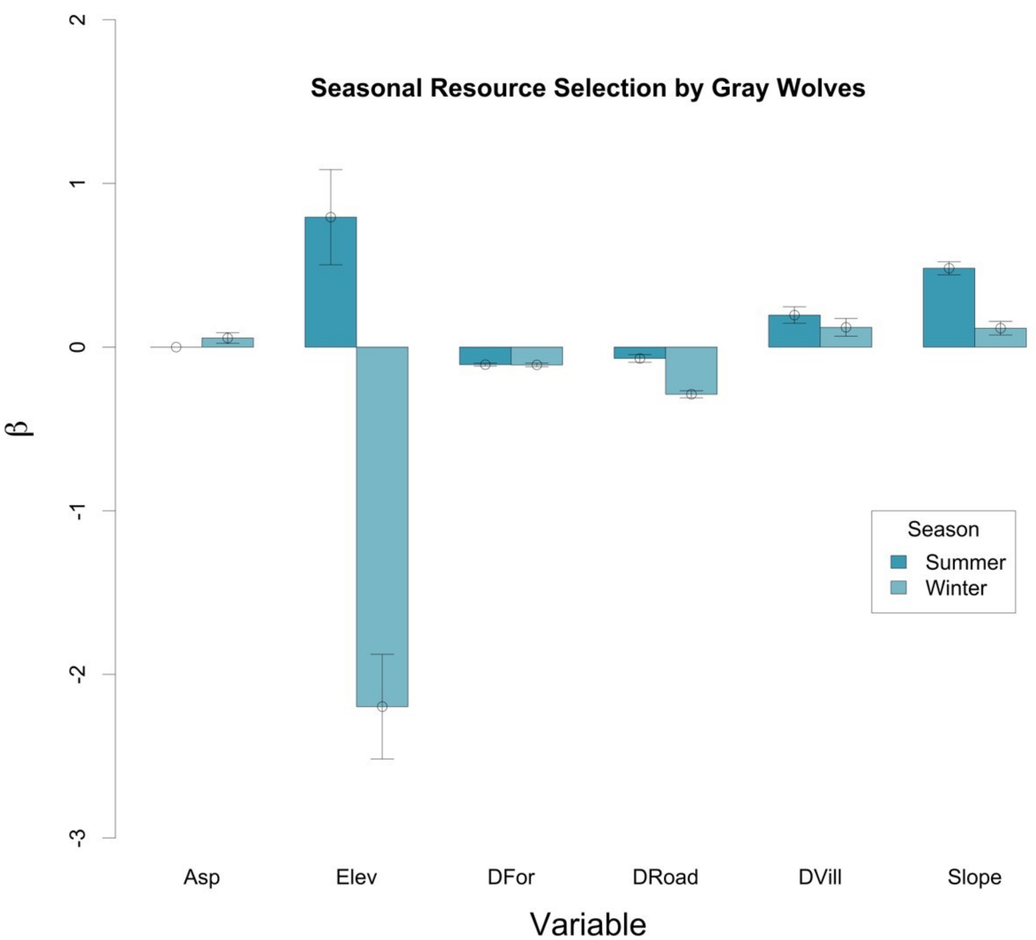

Figure 4.3. Seasonal resource selection by wolves in Sarıkamış forest, eastern Turkey. See Table 4.1 for descriptions of variables.

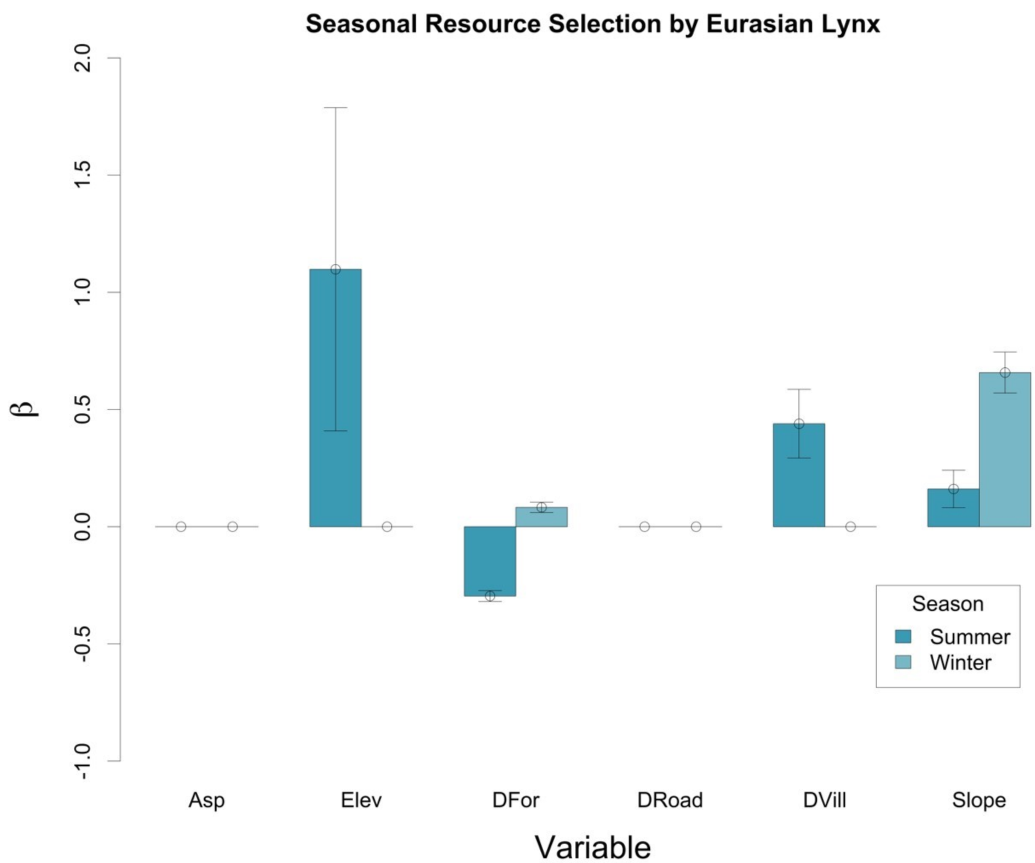

Figure 4.4. Seasonal resource selection by lynx in Sarıkamış forest, eastern Turkey. See Table 4.1 for descriptions of variables.

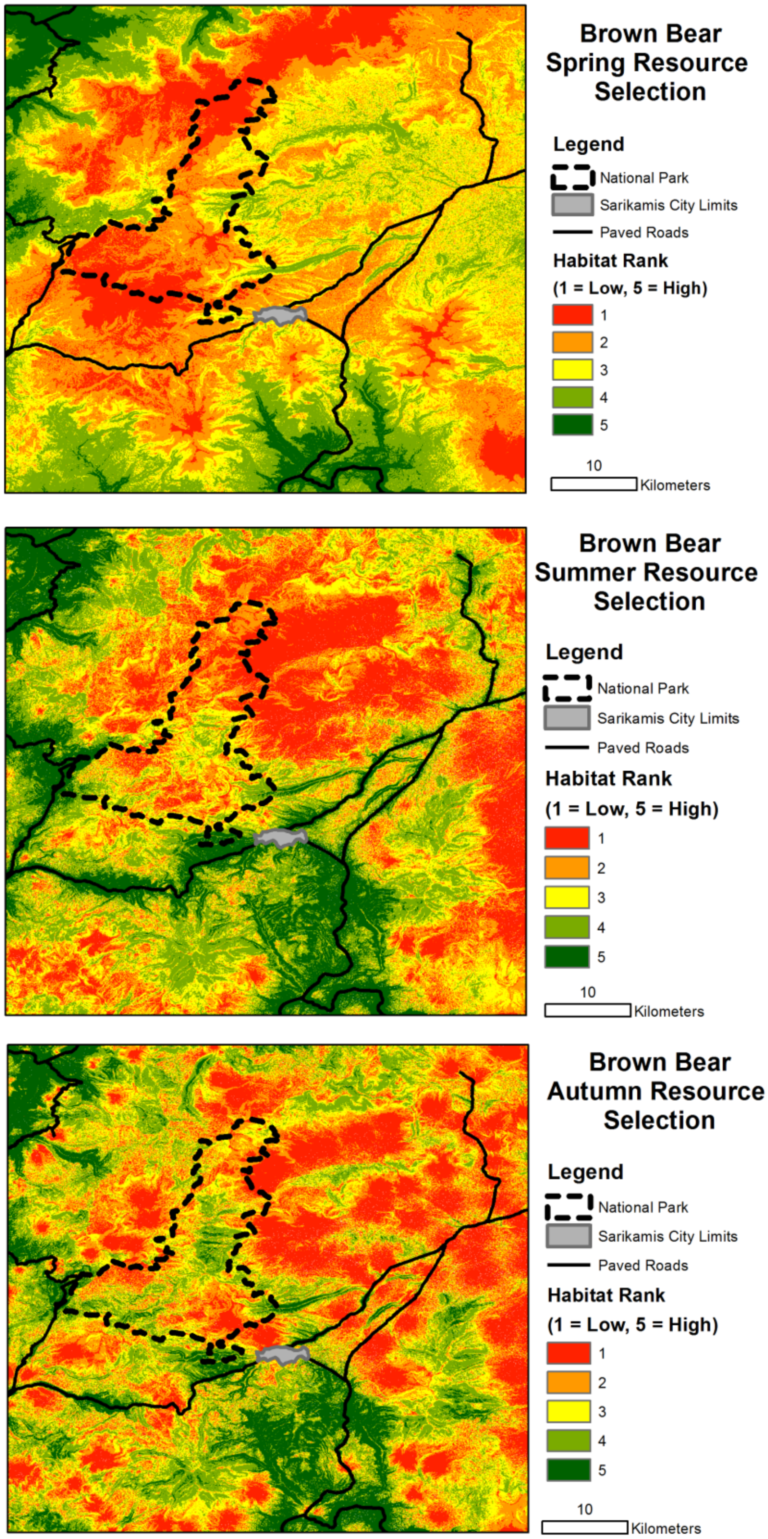

Figure 4.5. Predicted probability of bear occurrence in Sarıkamış forest, eastern Turkey during the spring season, the summer season, and the autumn season.

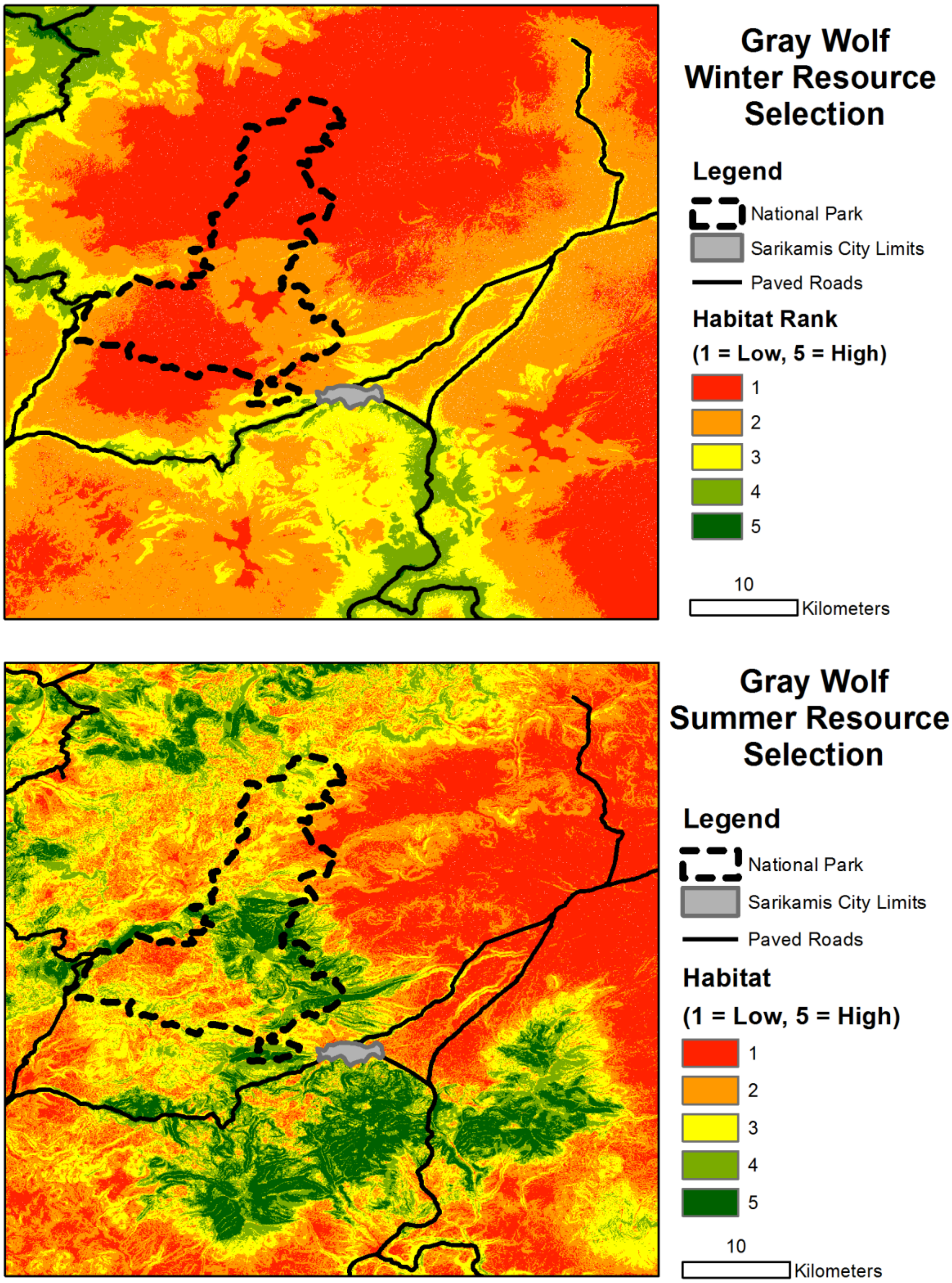

Figure 4.6. Predicted probability of wolf occurrence in Sarıkamış forest, eastern Turkey during the winter season and the summer season.

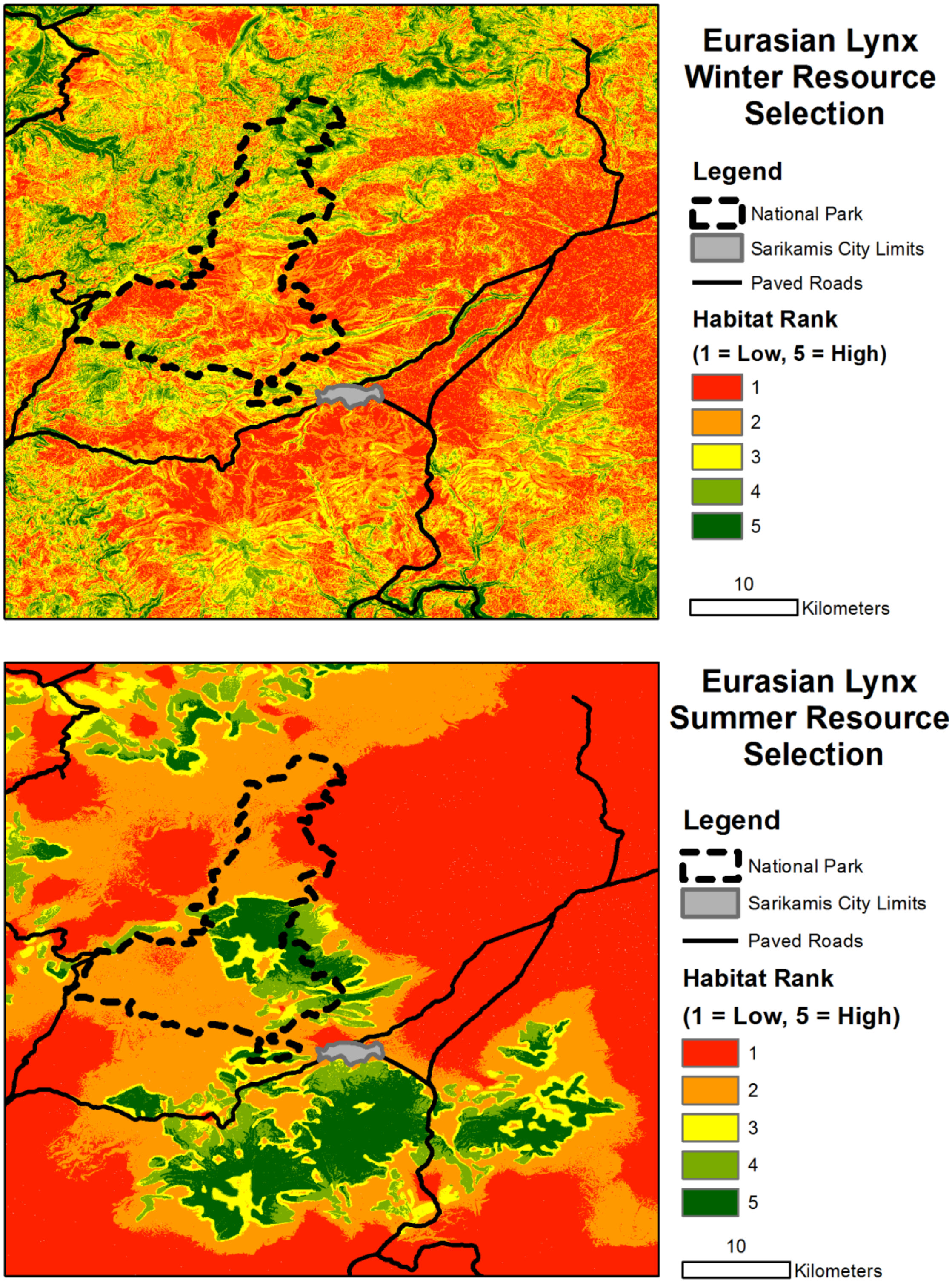

Figure 4.7. Predicted probability of lynx occurrence in Sarıkamış forest, eastern Turkey during the winter season and the summer season.

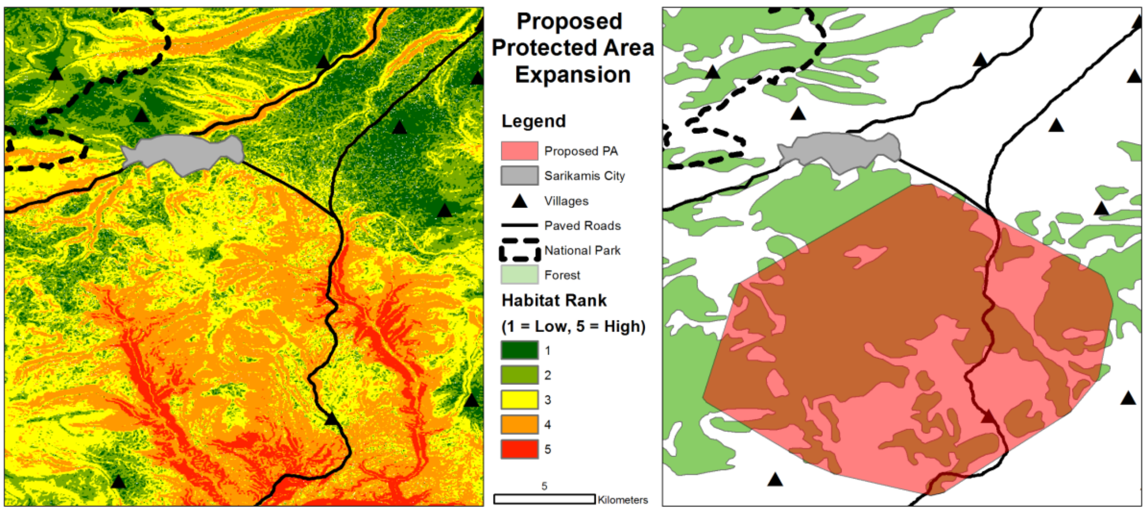

Figure 4.8. Prioritized area for future conservation efforts in Sarıkamış forest, eastern Turkey based on resource selection of brown bears, gray wolves, and Eurasian lynx.

Table 4.1. Description and characteristics of environmental variables used to model the probability of occurrence of bears, wolves, and lynx in Sarıkamış forest, eastern Turkey.

Group	**Variable Name**	**Abbrev.**	**Resolution (m)**	**Units**
Environmental	Distance to Forest	DFOR	30x30	Meters
	Elevation	ELEV	30x30	Meters
	Slope	SLP	30x30	Degrees
	Aspect	ASP	30x30	Degrees
Human	Distance to Road	DROAD	30x30	Meters
	Distance to Village	DVILL	30x30	Meters

Table 4.2. Home range sizes for all bears, wolves and lynx captured in Sarıkamış forest, eastern Turkey from 2011-2014.

Species	**Animal_ID**	**Sex**	**Age**	**Number of Locations**	**95% Kernel Home Range (km^2)**	**95% MCP Home Range (km^2)**
Wolf	2011_09435	M	7.5	2112	630	581
	2011_09436	M	2.5	1446	5938	4732
	2013_06823	F	4	1606	43	42
	2013_09435	M	5-6	1783	546	666
	2013_09436	F	5-6	674	153	125
	2014_09435	M	2.5	2042	762	797
	2014_09436	M	2.5	1632	769	1592
Lynx	2014_13148	M	4	1390	1966	1902
	2014_13151	M	7	1574	132	108
Bear	2012_07083	F	12-14	3359	29	27
	2012_07949	F	7	745	324	210
	2012_11685	M	8	9134	194	208
	2012_11686	M	6	1576	163	108
	2012_11687	M	6-7	8089	141	148
	2013_06089	F	5	5195	43	38
	2013_06090	F	10-12	7338	24	31
	2013_12262	M	>15	7824	117	137
	2013_12263	M	4	3053	130	108
	2014_11685	M	10	6497	234	232
	2014_11686	F	5	3737	31	31
	2014_15425	M	8-9	7571	86	84
	2014_15426	M	8-10	9440	120	155
	2014_15427	F	9-10	16497	14	17
	2014_15428	M	6	3635	34	72
	2014_15429	M	5-6	3714	77	142

CHAPTER 5

MINIMUM POPULATION SIZE AND GENETIC DIVERSITY OF BROWN BEARS WITHIN A FRAGMENTED POPULATION IN EASTERN TURKEY

5.1 Abstract

Estimating population size of wide-ranging and elusive carnivores is a major challenge for wildlife biologists and conservationists, yet it is also one of the most important population parameter estimates needed to guide management of wildlife. We evaluated a noninvasive method of capture-recapture for Eurasian brown bear (*Ursus arctos arctos*) density estimation using DNA extracted from scat samples in Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. This is a highly degraded forest that harbors a bear population that largely relies on anthropogenic food sources. From 2013-2015, we used scat detection dogs from the University of Washington's Center for Conservation Biology's Conservation Canines program to collect scat samples within a sampling grid designed to produce data for spatial capture-recapture modeling. We collected 1,520 bear scat samples across all years and after extracting DNA from 595 samples from the 2013 field season, we identified 157 viable bear samples to genotype using 8 polymorphic microsatellite loci. Logistic constraints were a limiting factor in our ability to generate enough data for capture-recapture analysis; therefore we focused on

generating a minimum population estimate in the main study area. Taking a multilocus genotyping approach, our results identified 27 unique multilocus genotypes, which suggests a minimum population size of 27 bears.

5.2 Introduction

The growing field of conservation genetics has become a keystone approach in wildlife research. Genetic variability of a species and its populations is an important component for evaluating long-term survival and consequent management approaches (Lacy 1997). Knowledge on genetic processes impacting populations can guide management decisions aimed at conserving or restoring genetic diversity, which is integral to the persistence of populations (Lande and Shannon 1996). Information on connectivity between populations is crucial to counteract the effects of genetic drift, which is particularly important for small or isolated populations (Schwartz et al. 2007). A standard approach in wildlife genetic monitoring is to use short tandem repeats (STRs) also known as microsatellites. STRs are short stretches of DNA made up of core repeats of two to seven nucleotides in noncoding regions of the genome (Allendorf and Luikart 2009). The combination of high polymorphism and neutrality to selection creates an ideal scenario to identify individuals. The use of STRs in wildlife management has become a common and increasingly sophisticated approach to monitor genetic diversity and gene flow in populations (Schwartz et al. 2007).

Using STRs, the minimum population size can be determined (number of unique individuals), and mark-recapture analysis can be conducted to determine effective population size (Skrbinšek et al. 2012). The latter is a crucial parameter that is difficult to determine without molecular genetic information in populations of wide-ranging and elusive carnivores. The minimum population size is critical for the sustainable management of wild populations because it may allow for deductions to be made about the current status and viability of a population. STRs can also be used to examine genetic diversity, which is influenced by such parameters as population size, the amount of gene flow to and from other populations and selection over time (Frankham 1996). Populations of wild animals are naturally structured or divided into separate groups where random mating occurs. Large carnivores, in particular, demonstrate spatial division due to isolation by distance and species-specific characteristics (e.g., social behavior and movement; Lowe & Allendorf 2010). Natural barriers such as topographic or water features can limit genetic connectivity; however, anthropogenic barriers such as roads, human activity, and habitat destruction can also cause population fragmentation (Geffen et al. 2004, Proctor et al. 2012). For this reason, knowledge of genetic connectivity can help mitigate human impact on large carnivore populations and guide management actions to increase genetic diversity and ultimately achieve management goals.

The aim of this study was to estimate the minimum population size of Eurasian brown bears in a presumably small and isolated subpopulation in northeastern Turkey. In this understudied region, the current population of bears and other wildlife species is unknown. However, previous work suggests a hyperabundance of large carnivores in the system that survives largely on anthropogenic food resources (Chynoweth et al. n.d., Capitani et al. 2016, Cozzi et al. 2016). Based on brown bear densities in forest habitats in Romania (Kalaber et al. 1994) and Georgia (Lexo Gavashelishvili, personal communication), we predict our study area (~550 km^2) to have 50-80 brown bears, although comparably drier forest conditions in Sarıkamıs makes it likely that the natural sustainable population is substantially lower.

5.3 Methods

5.3.1 Study Area (from section 3.3.1)

Our study was carried out on the Kars-Ardahan high plateau in northeastern Turkey, at the intersection of Caucasus and Irano-Anatolian global biodiversity hotspots. The area (c. 550 km^2; 40°20'N 42°35'E) ranges between 1900 and 3120 m asl and is composed of fragmented forest in a matrix of agricultural and rangelands. The city of Sarıkamış (population: c. 18,000) is located in the center of the study area and on one of the two paved roads that bisect the forested area. Forest cover consists almost exclusively of Scots pine (*Pinus sylvestris* Linnaeus, 1753), while understory vegetation is scarce, with consequent scarcity of food resources for browsers. Sarıkamış-Allahuekber Mountains National Park (hereafter SAMNP) boundaries cover a total area of 225.1 sq. km., but only include 49.69 sq. km. of forest. Therefore, SAMNP is only comprised of 22.07% forest cover. Total forest cover in the region includes 328.38 sq. km. including a large expanse of forest south of the national park (248.15 sq. km.). These patches of forest represent the southernmost significant forest patch in the region extending south from the extensive forests in the Black Sea Region of Turkey.

Human activity in the forest is extensive in both time and space, limited only by harsh winter temperatures, and consists primarily of livestock grazing, harvest of forest products (e.g., fruits, pine cones, mushrooms), and legal and illegal timber extraction. Livestock is abundant in the region with cattle (Bos taurus Linnaeus, 1758), sheep (Ovis aries Linnaeus, 1758), and goats (Capra hircus Linnaeus, 1758) freely roaming rangelands from April to November (Capitani et al. 2016). About 851,445 livestock heads have been registered in the Kars province in 2012 (Ministry of Food, Agriculture and Livestock, Republic of Turkey). A notable feature on the landscape is an unfenced municipal garbage dump 3 km west of Sarıkamıs city. The dump represents a predictable anthropogenic food source, and bears, wolves, and wild boar visit the dump regularly at night (pers. obs.). A portion of the bear population has altered life history strategies to regularly use the dump, while other bears never visit the dump (Cozzi et al. 2016).

5.3.2 Survey Methods

Scat samples were collected using scat detection dogs trained at the University of Washington's Center for Conservation Biology. These highly specialized dogs are trained to identify particular species and have proven to be remarkably efficient at scat collection (Wasser et al. 2004, 2011, Ayres et al. 2012). A sampling grid designed to produce data appropriate for spatial capture-recapture modeling was used to collect samples in a systematic method (Royle, Chandler, Sollmann, & Gardner, 2014; Figure 5.1). Each 30x30 km grid (black squares) contains fifteen 2x2 km sampling grids. The black grids represent a sampling area that is equivalent to the average home range size of our target species (based on preliminary data from our GPS collar work; see Chapter 4 of this dissertation). Three 2x2 grids within a single black grid were sampled per day, and each black grid was sampled 5 times in a rotating pattern. Overall, each 2x2 square was visited once to collect scat samples. The field team conducted all sampling within a 2-month period to satisfy the assumption of a closed population.

5.3.3 Lab Methods

Scat samples were collected in plastic bags and frozen (-20 °C) immediately subsequent to collection in the field in Sarıkamıs. Frozen samples were shipped to Boğaziçi University (Istanbul, Turkey) for DNA extraction (Qiagen QIAamp DNA Stool Mini Kit; see also Jackson et al., 2008) following manufacturers' instructions. All samples from 2013 were run at least once (n=595), and samples with unsuccessful extractions are currently being processed a second time for DNA extraction.

Extracted DNA samples were shipped to the University of Utah for further analysis. On arrival, samples were amplified by polymerase chain reaction (PCR) using bear specific primer pair G10P (Paetkau and Strobeck 1998) and run on a 2% agarose gel to confirm successful extraction of bear DNA from scat samples. Since extracting DNA from scat samples of various ages and qualities can be challenging and variable (Vynne et al. 2012), identifying nonviable samples early helped limit overall cost of microsatellite amplification and sequencing.

Samples containing bear DNA were amplified in a 10 µl reaction containing 2x Qiagen Master Mix (Qiagen Multiplex PCR Kit, Qiagen, USA), 1.3 µM of forward primer, 5.3 µM of reverse primer, 3.3 µM of fluorescent tag, 1 µl of Q mix and 3 µl of template DNA. Cycling conditions were as follows: 95 °C for 15 minutes, 32 cycles of 30 seconds at 94 °C, 90 seconds at 58 °C, 1 minute at 72 °C, and 10 minute final extension at 72 °C. Fluorescent tags NED, PET, 6FAM, VIC were used to enable allele reads on a capillary sequencer.

Samples were genotyped using eight polymorphic microsatellite loci which were shown to contain enough variation to identify individual bears across all eight ursid species (Paetkau and Strobeck 1994, 1998): G1A, G10B, G10C, G1D, G10L, G10M, G10P, and G10X. All loci were amplified in three multiplex PCR reactions using Qiagen Multiplex PCR Kit, run on an Applied Biosystems 3730xl capillary sequencer (University of Utah Cores Research Facility), and analyzed with PeakScanner Software. Peaks were read at the tetra level to account for low peak reading on the capillary sequencer and reduce human error. Genotyping errors can result in positive bias if samples from the same individual are assigned different genotypes (Woods et al. 1999, Mills et al. 2000). Conversely, if the markers are not sufficiently variable, too few individuals will be identified resulting in a negative bias. We used a combination of objective (peak height) and subjective (appearance) criteria to quantify fragment size (i.e., length) as genotype scores, and classified microsatellites as tetra-STRs to account for low peaks in many of our samples.

5.3.4 Multilocus Genotype Analysis

To estimate the minimum population size for bears, we used multilocus genotyping (MLG). Missing data due to unsuccessful PCRs were identified as an issue early in the process, and we therefore only used loci with 30% or less missing data. We first called MLG by a naïve method, whereby coding missing information as 0 and treating it as another state. This resulted in 122 unique MLGs; however, because of the high degree of uncertainty that this method brought, we tried to resolve this problem by quantify the genetic distance between each individual and collapsing individuals under a defined threshold. To this end, we built a distance matrix between each individual using Nei's genetic distance (Nei 1978), which calculates distance between individuals based on the arithmetic mean of gene identity (the probability of two individuals having the same allele at a particular locus summed over all loci; Nei 1978).

To identify the minimum threshold separating two individuals, we used the above distance matrix to build a hierarchical cluster tree based on the nearest and farthest neighbor approaches (also known as single linkage and complete linkage clustering respectively, Legendre and Legendre 1998). In both trees we found the average minimum distance between two individuals to be close to 0.02 (nearest neighbor: 0.02083333, farthest neighbor: 0.01785714). We therefore used 0.02 as a cutoff to collapse individuals. To investigate the effect of our threshold, we also collapsed individuals by an extremely small genetic distance (1.5^{-8}) and did not see different results. When we went over the threshold of 0.02, we started to reduce the number of MLGs. Therefore we believe our approach to collapsing MLGs is appropriate.

5.4 Results

Between 2013-2015, we encountered 5,125 scat samples from nine known mammal species, from which we collected 1,520 bear scat samples (Table 5.1). Out of the 595 bear samples collected in 2013 we were able successfully extract DNA from 157 samples. Of these 157 samples, we excluded samples outside the main study area (Figure 5.1) and those that did not have information from at least 5 microsatellite loci, resulting in a final sample size of 126. We experienced varying degrees of success amplifying STRs for the 8 microsatellite loci and had to remove 1 locus (G10M) from further analysis due to high amount of missing data (Figure 5.2).

A genotype accumulation curve for 7 microsatellite loci suggests that 5-6 loci provide enough resolution to identify unique MLGs (Figure 5.4). Across 7 loci (mean Hexp: 0.701355176; mean Evenness: 0.819339375; see Table 5.2) we identified 27 MLGs. Based on these 27 MLGs, genotypic diversity according to Shannon's Index was 3.121751, Simpson's Index was 0.947972, and expected genotypic heterozygosity was 0.701355176. Our recapture history for individual MLGs suggests a robust data set to move forward with spatial capture-recapture analysis once more samples are genotyped (Figure 5.5).

5.5 Discussion

Our results are the first attempt to estimate minimum population size of brown bears in a region of Turkey using molecular fingerprinting, and as such we encountered some challenging conditions that delayed tissue processing and shipping of DNA samples that significantly slowed progress. As a result, we were forced to work with a smaller number of samples for estimating minimum population size of brown bears in Sarıkamıs forest than initially intended. Therefore, our minimum population estimate is more than likely an underestimate of the true population size, and by including more samples in the future we aim to generate a more accurate estimate of population size.

To deal with uncertainties in MLG calls caused by the high amount of missing data we treated individuals that had a genetic distance under 0.02 (according to Nei's distance, Nei 1972) as one. This is a somewhat conservative approach as we only collapsed individuals that were extremely close genetically. However, this method does have the risk of collapsing siblings since MLG profiles of siblings have the risk of being extremely close due to the high amount of missing data. For this reason, and due to samples that did not provide viable bear DNA, our minimum population estimate is most likely lower than the true minimum population. A solution to this problem is to rerun viable DNA samples to fill in data gaps (see Figure 5.2), and also to continue DNA extraction for samples that to date have not provided viable bear DNA.

Bases on our results, the bear population in Sarıkamıs forest appears to be a relatively diverse population. By comparing nuclear genetic diversity from other studies based on expected heterozygosity, Sarıkamıs bears are similar to Dinaric and Scandanavian bear populations, more genetically diverse than isolated populations such as in the Italian Apennines and Pyrenees, and slightly less diverse than areas with good conservation status, such as the Carpathian Mountains in Romania (Kocijan et al. 2011). The southernmost patch of forest in the region, Sarıkamıs is a somewhat isolated, but bears have been documented migrating between forest patches (Cozzi et al. 2016), validating results presented here that suggest high genetic diversity. However, ongoing development in the region threatens this connectivity and should be seen as a real threat (Şekercioğlu et al. 2011, Ambarlı et al. 2016).

Given our limitations, we were able to generate a robust minimum population estimate of 27 unique MLGs in our study area. This estimate corroborates previous observations in the field, based on ongoing bear capture efforts for GPS collar deployment (see Chapter 4: 25 unique individuals) and observations of bears at the municipal garbage dump (~33 individuals seen in one night, author's pers observation).

A minimum population estimate allows us to speculate that the minimum local population density of bears in Sarıkamıs Forest is above 8.23 bears/100 km^2. This estimate is similar to values generated from other studies ranging from 2.73 – 13 bears per 100 km^2 (Revenko 1995, Miller et al. 1997, Bellemain et al. 2005, Walsh et al. 2010, Morton et al. 2016). However, our estimate of minimum local bear density is still above average, and therefore, we speculate that true bear density in Sarıkamıs is significantly higher than in most regions within the global distribution of brown bears. It is unlikely that bear density in Sarıkamıs surpasses the highest reported local bear density in the Dinaric Mountains of Slovenia at 40 bears/100 km^2, which is a result of a long cultural history of supplemental feeding and hunting (Jerina et al. 2013).

5.6 Conclusions

Genetic sampling using scat samples was effective in estimating a minimum population size for Eurasian brown bears in Sarıkamıs forest. These preliminary results indicate that this method can be an important tool for carnivore management in this understudied system largely due to the ease of collecting fecal samples compared to the cost of other methods such as large carnivore capture. Moving forward, successful genotyping of more samples will allow for spatially explicit capture-recapture models to be used to estimate effective population size of brown bears, gray wolves, and Eurasian lynx in the study area (Chandler and Andrew Royle 2013). In addition, samples could continuously be collected in the study system to examine long-term trends in survival and fecundity. Genetic sampling is increasingly becoming a reliable alternative to other methods to estimate large carnivore populations and should be considered as a principal approach for studying large carnivore populations in Sarıkamıs forest in the future.

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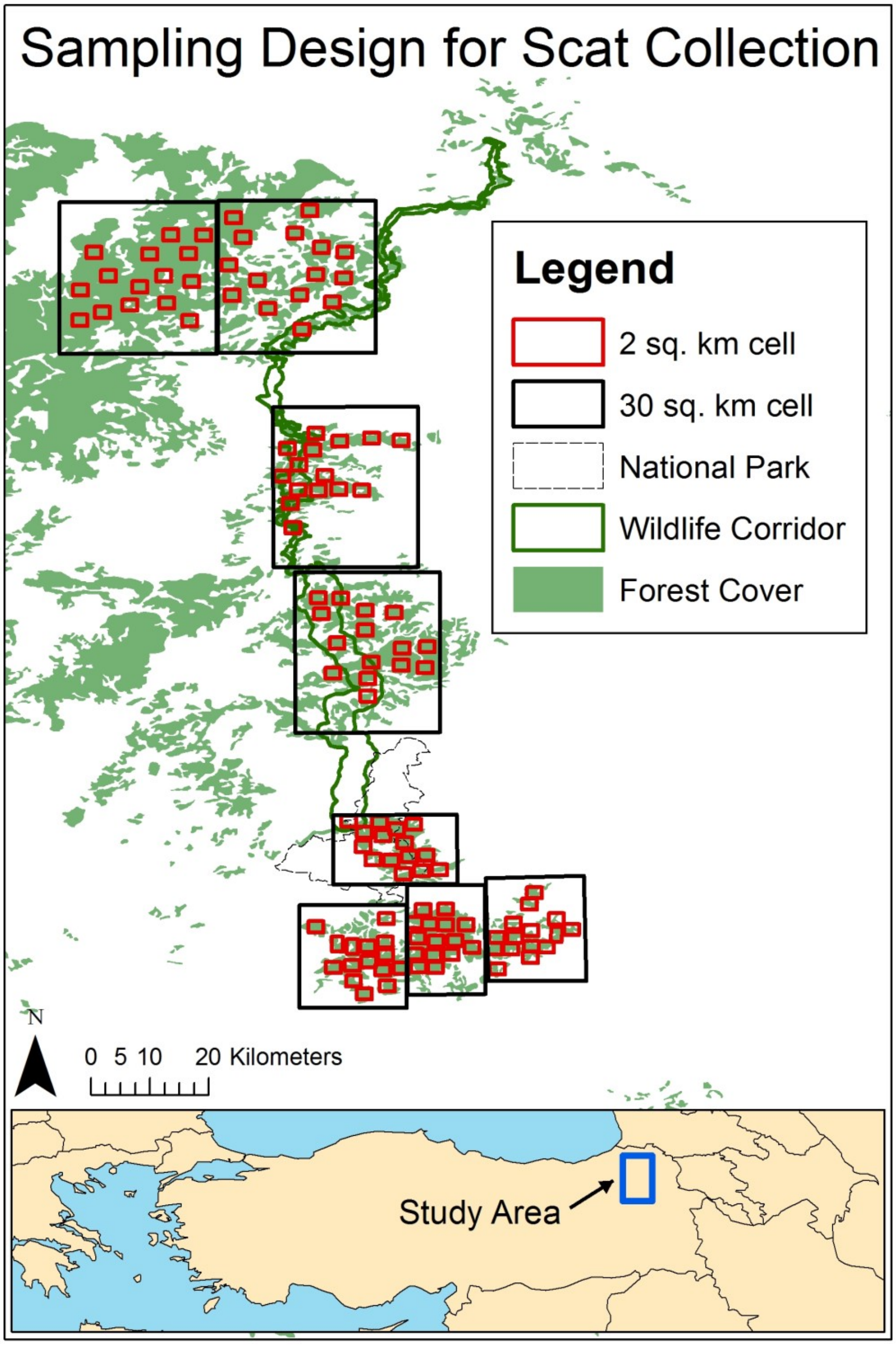

Figure 5.1. Black sampling grids (30x30km) are based on home size of target species and will be resampled 5 times to produce data appropriate for capture-recapture analysis. SAM NP, surrounding forests, and the entire proposed wildlife corridor region will be sampled, providing a holistic picture of large carnivore genetics in the region.

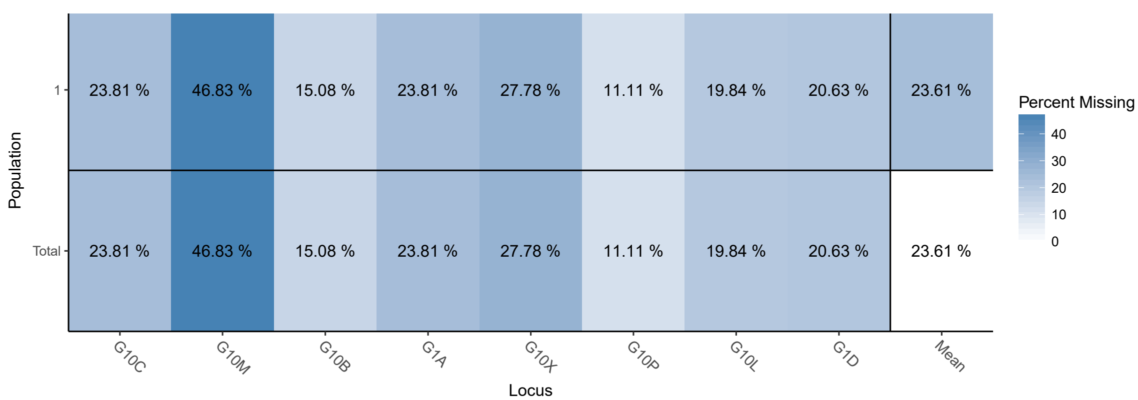

Figure 5.2. Percent missing data per locus for all 8 loci originally used for genotyping bears. Loci G10C was identified as having too much missing data to include in further genotyping.

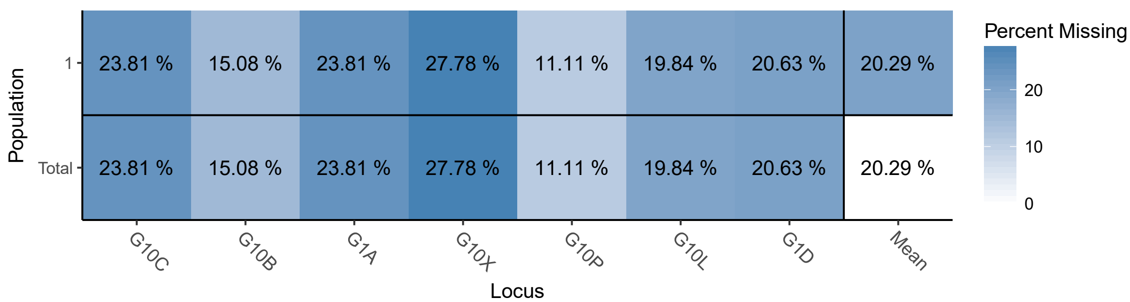

Figure 5.3. Percent missing data per locus for the 7 loci used for genotyping bears, after loci G10M was removed from analysis.

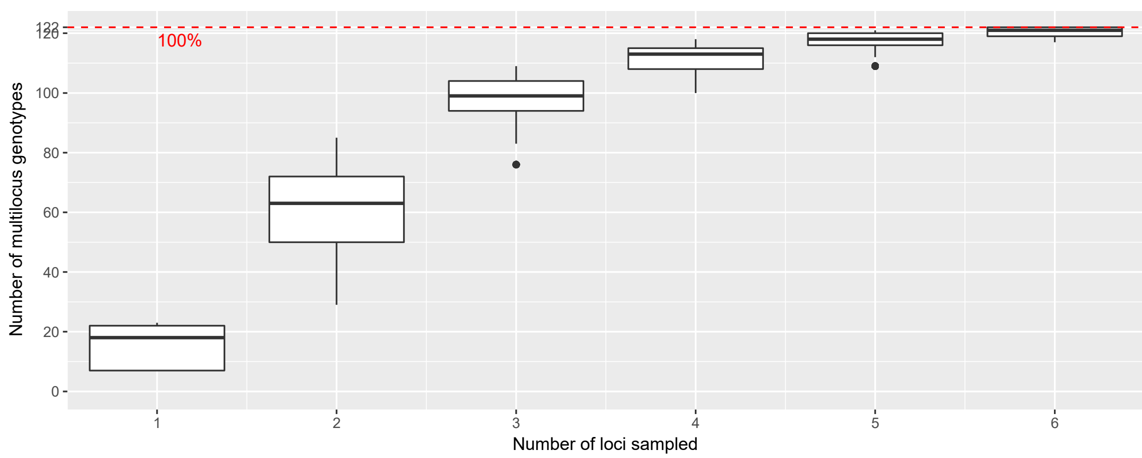

Figure 5.4. Genotype accumulation curve for 7 microsatellite loci used to genotype bears.

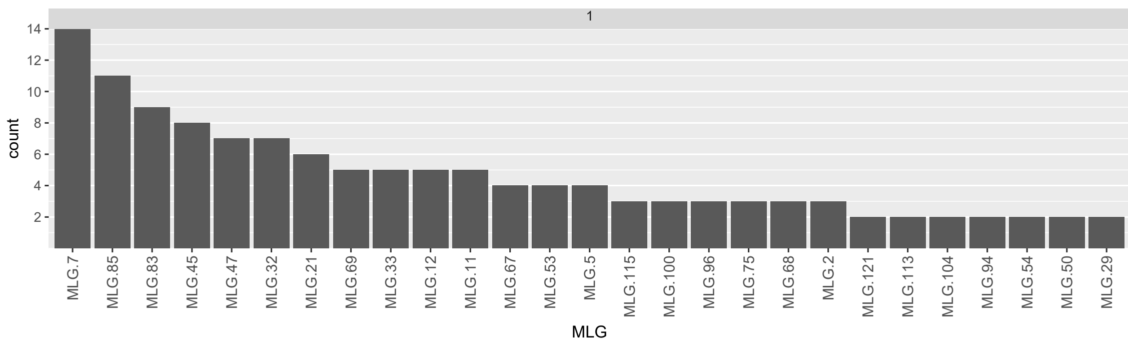

Figure 5.5. Multilocus genotype (MLG) recaptures for 27 MLGs identified with 7 microsatellite loci for bears.

Table 5.1. Summary of all scat samples encountered in a survey conducted from 2013-2015 in Sarıkamış, eastern Turkey using trained scat-detection dogs.

	2013		2014		2015*	
Species	**Encounter**	**Collect**	**Encounter**	**Collect**	**Encounter**	**Collect**
Bear	1379	595	1311	783	187	142
Wolf	326	139	394	326	75	62
Lynx	93	51	141	121	14	13
Wild_Boar	158	78	395	49	31	28
Badger	53	37	56	23	23	19
Marten	86	44	180	47	56	47
Mustelid	0	0	0	0	13	10
Roe deer	3	3	25	17	29	21
Hedgehog	2	0	0	0	0	0
Wildcat	3	3	9	9	0	0
null	44	39	30	28	0	0
blank	0	0	0	0	8	8
Total	**2147**	**989**	**2542**	**1404**	**436**	**350**

*During our 2015 field season, we were arrested during field work and could not continue data collection

Table 5.2. Microsatellite marker variability, expected heterozygosity and observed number of alleles of brown bears in Sarıkamış forest, eastern Turkey, 2013.

Locus	**N[a]**	**1-D[b]**	**Hexp[c]**	**Evenness[d]**
G10C	7	0.7734375	0.777486911	0.832836756
G10B	6	0.77198882	0.775613181	0.862228567
G1A	4	0.559082031	0.562009162	0.793323241
G10X	5	0.518294892	0.5211584	0.832395194
G10P	7	0.760044643	0.763452915	0.767265801
G10L	8	0.788256053	0.792177725	0.859223055
G1D	5	0.714	0.71758794	0.788103012
Mean	6	0.697871991	0.701355176	0.819339375

[a] no. of observed alleles
[b] Simpson's Index
[c] observed heterozygosity
[d] evenness

CHAPTER 6

HUMAN-WILDLIFE CONFLICT AS A BARRIER TO LARGE CARNIVORE MANAGEMENT AND CONSERVATION IN TURKEY

Chynoweth, M. W., E. Çoban, Ç. Altın, and Ç. H. Şekercioğlu. 2016. Human–wildlife conflict as a barrier to large carnivore management and conservation in Turkey. Turkish Journal of Zoology 40:972–983. Reprinted with permission from the Scientific and Technological Research Council of Turkey.

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Human–wildlife conflict as a barrier to large carnivore management and conservation in Turkey

Mark W. CHYNOWETH[1,*], Emrah ÇOBAN[2], Çağatay ALTIN[3], Çağan H. ŞEKERCIOĞLU[1,2,4]
[1]Department of Biology, University of Utah, Salt Lake City, Utah, USA
[2]KuzeyDoğa Society, Kars, Turkey
[3]Alaşehir Vocational School, Celal Bayar University, Manisa, Turkey
[4]College of Sciences, Koç University, İstanbul, Turkey

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Abstract: Large carnivorous mammals are wide-ranging animals and thus frequently come into contact with human settlements in agrarian landscapes. This often generates human–wildlife conflict; carnivores potentially damage livestock, agricultural products, or human well-being. In Turkey, the cooccurrence of eight medium-large carnivore species combined with a burgeoning human population and unsustainable consumption of natural resources increasingly threatens carnivore populations. To better understand human–wildlife conflict in Turkey and provide potential solutions, we conducted 959 human opinion surveys in 2006, 2010, and 2014 in 58 distinct settlements surrounding the Sarıkamış-Allahuekber Mountains National Park in Kars, Ardahan, and Erzurum provinces. Results show that respondents regularly interact with large carnivores and 77.2% experience harm from wildlife, typically in the form of damage to agricultural fields and livestock. Farmers and shepherds are more likely to have a negative perspective of carnivores than students, shopkeepers, and laborers. However, human perceptions of carnivores and the desire to be involved with ecotourism are improving over time. These results suggest that human perceptions of wildlife are a barrier to conservation and management of wildlife populations. The research, education, and outreach framework outlined here can be used to address human–wildlife conflict across Turkey and guide ongoing conservation efforts of Turkey's existing, and increasingly threatened, large carnivores.

Key words: Anatolia, Caucasian lynx, brown bear, gray wolf, human–wildlife conflict, large carnivore, mammal ecology, opinion survey, sustainability, wild boar

1. Introduction

Large carnivores constitute a naturally rare, ecologically important, and increasingly threatened group of mammals (Ripple et al., 2014). Across the globe their populations are at risk as a result of habitat loss, depletion of natural prey base, and direct persecution (IUCN, 2015). The large habitat requirements and trophic level of carnivores can increase these risks by generating potential human–wildlife conflict, primarily due to livestock depredation (Muhly and Musiani, 2009) or damage to agricultural products (Northrup et al., 2012). However, adaptive management and reintroduction programs have proven effective in some regions of the world, such as North America (Smith and Bangs, 2009) and Europe (Chapron et al., 2014), demonstrating that humans and large carnivores can coexist on the landscape. In Turkey, a diverse group of carnivores and unique sociopolitical conditions present a noteworthy challenge for scientists, wildlife managers, and policy makers to develop solutions to ongoing, and potentially growing, human–wildlife conflicts.

Turkey is a country rich in biodiversity, as the only country almost completely covered by three of the world's biodiversity hotspots, the Caucasus, Irano-Anatolia, and the Mediterranean (Şekercioğlu et al., 2011b). Across its diverse landscape, Turkey hosts an impressive assemblage wildlife, including 22 potential carnivore species, of which eight species may potentially generate human–wildlife conflicts (Table). These eight species range across a variety of habitats that essentially cover the entire country (Figure 1). Each of these species has unique ecological requirements for survival. In the face of increasing human activity fueled by a development-driven economic agenda (Şekercioğlu et al., 2011a), these requirements are jeopardized and large carnivores are increasingly coming into conflict with humans. More research is urgently needed to understand

Table. Extant carnivore species in Turkey. Gray shading indicates medium-large carnivores that may cause human–wildlife conflict. The Caspian tiger (*Panthera tigris virgata*) has been extinct since the 1970s (Can, 2004).

Family	Genus	Species	Subspecies	English common name	IUCN status*
Felidae	*Caracal*	*caracal*		Caracal	LC
	Felis	*chaus*		Jungle cat	LC
	Felis	*sylvestris*		Wildcat	LC
	Lynx	*lynx*		Eurasian lynx	NT
	Acinoyx	*jubatus*	*venaticus*	Asiatic cheetah[a]	CR
	Panthera	*pardus*	*ciscaucasica*	Persian leopard[b]	EN
	Panthera	*leo*	*persica*	Asiatic lion[a]	EN
Herpestidae	*Herpestes*	*ichneumon*		Egyptian mongoose	LC
Hyaenidae	*Hyaena*	*hyaena*		Striped hyena	NT
Canidae	*Vulpes*	*vulpes*		Red fox	LC
	Canis	*aureus*		Golden jackal	LC
	Canis	*lupus*		Gray wolf	LC
Ursus	*Ursus*	*arctos*		Eurasian brown bear	LC
Mustelidae	*Mustela*	*ermina*		Stoat	LC
	Mustela	*nivalis*		Least weasel	LC
	Mustela	*putorius*		European polecat	LC
	Vormela	*peregusna*		Marbled polecat	VU
	Martes	*foina*		Beech marten	LC
	Martes	*martes*		Pine marten	LC
	Meles	*meles*		Eurasian badger	LC
	Lutra	*lutra*		European otter	NT
Phocidae	*Monachus*	*monachus*		Mediterranean monk seal	CR

*LC = Least concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered
[a]Not currently observed in Turkey.
[b]Rarely observed in Turkey, most recently in 2013.

how to mitigate these conflicts and promote coexistence of humans and carnivores on the landscape.

Turkey's mammals are largely understudied; however, research is increasing in recent years, as demonstrated by this current *Turkish Journal of Zoology* special issue. Ongoing work suggests that threats to large carnivores are similar to threats to other biodiversity that exist throughout these species' ranges. Obligate carnivores, including felids like Eurasian lynx (*Lynx lynx*) and caracal (*Caracal caracal*), rely on intact habitat and a sufficient natural prey base, making them particularly susceptible to these threats. However, many other carnivore species can utilize modified habitats and anthropogenic food sources to supplement or sustain their ecological needs (Bateman and Fleming, 2012; Tourani et al., 2014; Kavčič et al., 2015). Preliminary work in Turkey suggests that some large carnivores may exhibit synanthropic behavior, relying on human activity (e.g., livestock, garbage) as a major food source (Capitani et al., 2015). This phenomenon is observed in many other parts of the world, particularly brown bears feeding at garbage dumps (Peirce and Van Daele, 2006) and gray wolves preying on livestock (Muhly and Musiani, 2009).

Turkey's burgeoning human population, currently estimated to be over 76 million by the World Bank, indirectly contributes to all three major threats to carnivores

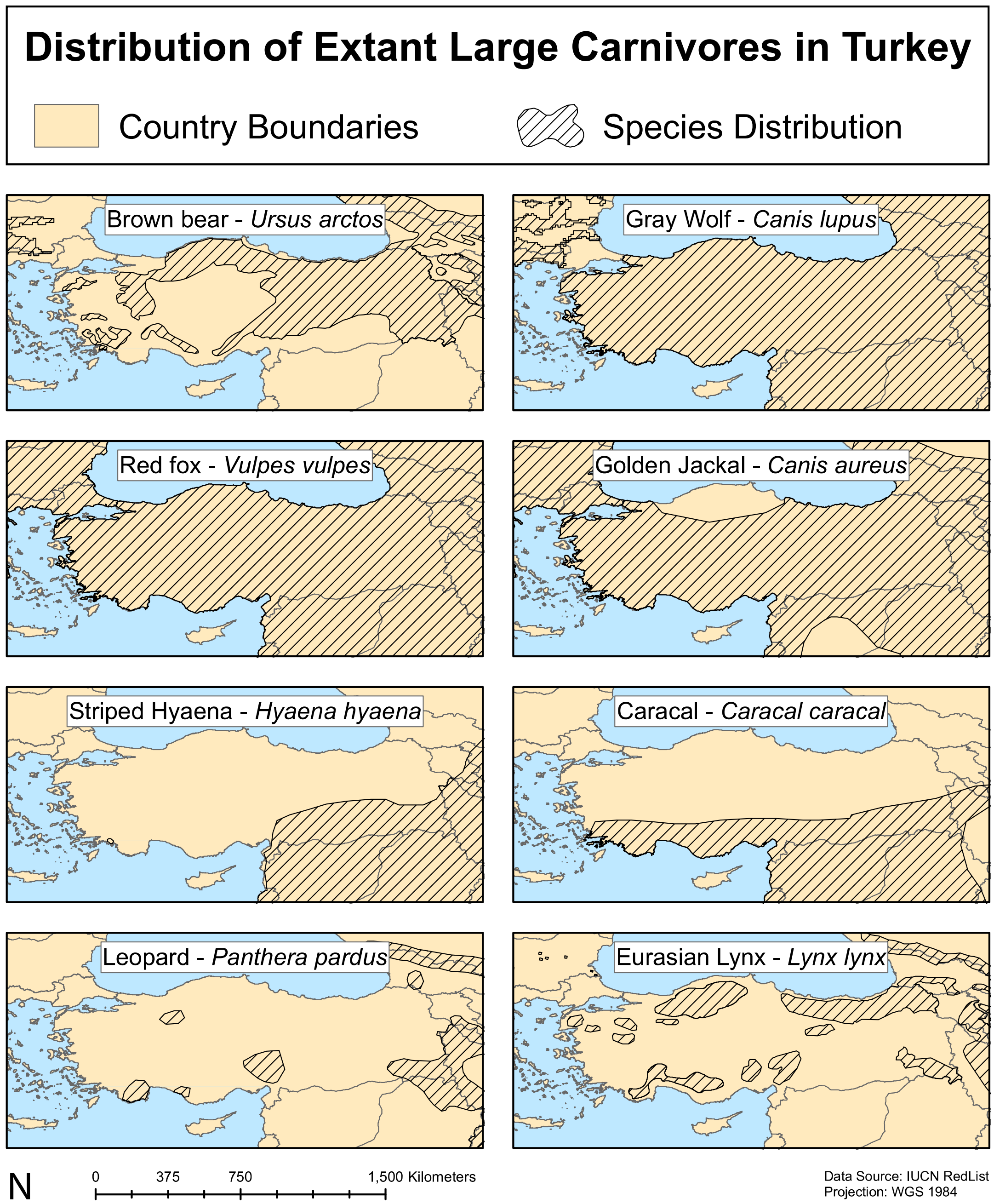

Figure 1. Spatial distribution (based on IUCN data) of Turkey's eight medium to large carnivores that may potentially cause human wildlife conflict.

through increasing development and consumption of natural resources, which degrades the habitat that large carnivores rely on for existence. However, human impact on the natural environment is complex, and social and demographic changes do not always have predictable results. For example, Turkey's rural population is gradually migrating to urban areas, lessening direct human impact on more remote areas of the country. Without proper management of the areas that large carnivores inhabit, the populations that may be partially dependent on anthropogenic food sources may experience population declines. To ensure the longevity of large carnivore populations across Turkey's diverse landscape, continuous monitoring and evaluation of wildlife populations is critical to understand these complex relationships and to ensure the success of management programs.

Human dimensions of wildlife management are critical to the success of a wildlife management program (Treves and Karanth, 2003) and as large carnivore conservation initiatives become established in Turkey, it is important to include a human dimension of wildlife management. The input of stakeholders at the local level can help determine how governments or conservation organizations can mitigate potential human–wildlife conflicts. Reducing conflict will increase human tolerance of large carnivores and allow for the coexistence of humans and large carnivores in a landscape. To determine what strategies are needed to reduce conflict, scientists and managers must understand the conflicts that exist on a local level. Understanding human–wildlife conflict in Turkey is particularly challenging because of the diverse ecosystems that are distributed across the country, the dynamic sociopolitical environment, and the lack of infrastructure and resources that exist for wildlife research and management. For our research, we are currently focused on working with large carnivores on the Kars-Ardahan Plateau in eastern Turkey, a largely agricultural landscape dominated by livestock husbandry and grain production.

In the Sarıkamış-Allahuekber Mountains National Park and surrounding forests in northeastern Turkey, large carnivores are facing increasing threats due to human activity. Villagers in this area have an integral relationship with the forest, which provides firewood, grazing areas, and recreational opportunities. Similar to global threats to carnivores, this human activity decreases and fragments habitat, reduces the natural prey base, and puts animals at risk of vehicle collisions, poaching, and direct persecution. To provide a comprehensive conservation and management plan, we are conducting long-term monitoring of large carnivores, including a community outreach program. As part of this program, we are conducting surveys in villages surrounding the national park. Our objective is to understand the opinions of local villagers concerning large carnivore presence and abundance, wildlife management, and designation of protected areas. To achieve this objective and as part of the KuzeyDoğa Society's ongoing large carnivore research in eastern Turkey, we have surveyed residents over the last 8 years to gain a better understanding of existing human–wildlife conflict and to mitigate future conflicts in an effort to promote coexistence of large carnivores and humans in rural areas of Turkey.

2. Materials and methods

2.1. Study area

The Sarıkamış-Allahuekber Mountains National Park (40°24′51″N, 42°30′43″E) lies on the border of Kars and Erzurum provinces in northeastern Turkey (Figure 2). This national park was established in 2004 as a monument to honor an important battle between the armies of the Ottoman and Russian empires from December 1914 to January 1915, as part of the Caucasus Campaign of World War I. The national park covers 225 km^2; however, since the boundaries are based on historical events instead of biological data, only 22% (or 50 km^2) of the park's area has forest cover. Total forested areas within and outside the park include a large fragmented coniferous forest of approximately 326 km^2, dominated by Scots pine (*Pinus sylvestris* L.). The national park and surrounding forests is the southernmost patch of intact forest in a matrix of agricultural fields and rangelands. Turkey's first wildlife corridor will connect this isolated patch of forest to the larger forests of the Black Sea Region and Caucasus Mountains (http://newswatch.nationalgeographic.com/2012/02/13/turkeys-first-wildlife-corridor-links-bear-wolf-and-lynx-populations-to-the-caucasus-forests/).

Notable mammalian carnivores of the Sarıkamış-Allahuekber Mountains National Park include Eurasian brown bears (*Ursus arctos arctos*), gray wolves (*Canis lupus*), Caucasian lynx (*Lynx lynx dinniki*), wildcat (*Felis silvestris*), and beech marten (*Martes foina*). Prey species include wild boar (*Sus scrofa*), Eurasian hare (*Lepus europaeus*), and roe deer (*Capreolus capreolus*). However, based on the authors' ongoing camera trap work, prey species are exceptionally rare, particularly roe deer. Forested areas and surrounding meadows are largely dominated by human activity including grazing livestock, gathering forest products, and grain production.

Agropastoralist communities have inhabited the region for millennia and the impact of current and past human activity is ubiquitous across the landscape. The current human population in the study area is approximately 85,000 people in hundreds of small-medium villages surrounding the town of Sarıkamış (population approx. 22,000). The livestock assemblage includes cattle, sheep, and goats for livestock production and horses and donkeys as common work animals. Stock are typically shepherded to pastures each morning and secured in pens from April to November. Small-scale land holdings produce subsistence crops, small orchards, apiaries, and fodder for livestock in the winter.

2.2. Sampling design

In 2006, 2010, and 2014, the KuzeyDoğa Society worked with volunteers to conduct opinion surveys with residents of villages and towns surrounding the Sarıkamış-Allahuekber Mountains National Park and surrounding

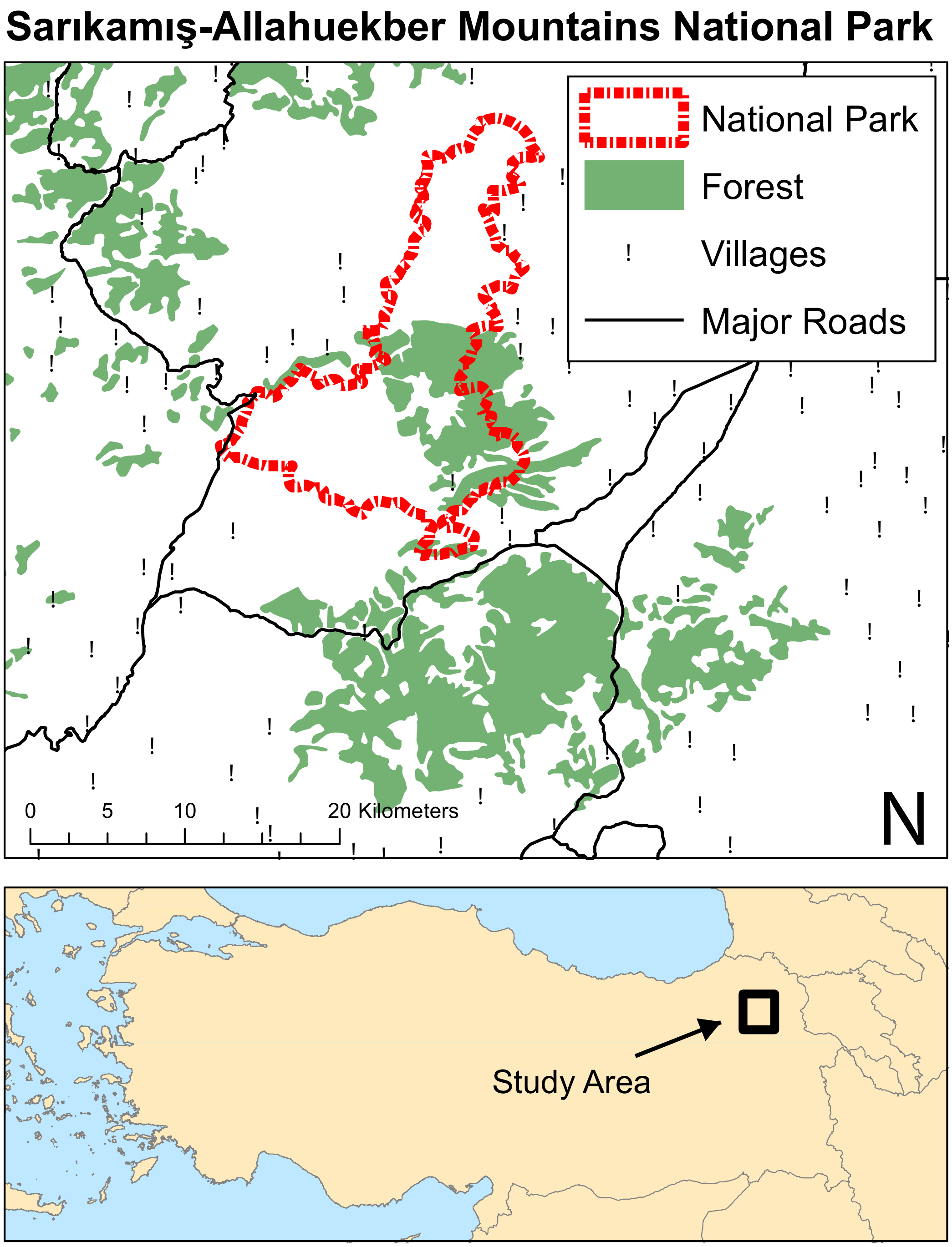

Figure 2. Sarıkamış-Allahuekber Mountains National Park and surrounding forests in eastern Turkey.

forests. The majority of surveys were conducted during visits to village or city centers. All villages within a 30-km radius of the center of the study area were targeted for visits to conduct surveys. Citizens were approached and asked if they would like to participate in an opinion survey about local wildlife and given an option to participate.

In addition, surveys were conducted opportunistically outside of population centers when we encountered shepherds, farmers, or other local residents in the forest. We only surveyed individuals greater than 15 years of age and residing in towns or villages within the study area. Some individuals were not interested in taking a survey, but shared opinions and stories about wildlife in their surrounding environment.

Survey questions were designed to characterize general human perceptions of wildlife and gather specific information about large carnivores. The survey focused on Eurasian brown bears, gray wolves, Caucasian lynx, and wild boar. All these species are known to exist in the study area based on previous fieldwork. While wild boar is not a large carnivore, this species is relatively abundant in the study area and is a known agricultural pest that contributes to human–wildlife conflict. The survey consisted of 17 questions, 13 of which were multiple choice and 4 open-ended questions. All questions had an "other" option where respondents could write in their own answer or further explanation if needed. A trained bilingual professional translated completed surveys, and any indirect translations were examined and discussed with local biologists to reach an appropriate translation.

3. Results

A total of 959 individuals from 58 distinct towns or villages responded to the survey (Figure 3). In 2006, 2010, and 2014, we had 46, 684, and 229 survey respondents, respectively. Across all survey years, respondents were 80.1% male, ranging in age from 16 to 83 years, and the two most common occupations were farmer and student (Figure 4). Wildlife is most often seen in the forest, followed by near a village and at a garbage dump (Figure 5). However, most respondents (82.5%) reported seeing wildlife in or around their village, of whom 50.6% see bears, wolves or wild boar every day.

Across all years, 77.2% of respondents reported experiencing harm from wildlife; however, survey respondents in 2014 were less likely to report a negative experience than respondents in 2006 or 2010 (Figure 6). For respondents who reported harm, the two most frequent property types damaged by wildlife were livestock and crops (Figure 7). The two most frequent reactions to encountering wildlife were relying on guard dogs, avoiding areas known to have large carnivores, and having firearms. Fewer people reported using firearms and more people reported avoiding large carnivores in 2014 compared to 2010 (Figure 8). Both bears and wolves are perceived as a significant threat by many respondents (anecdotal) and 41.6% of respondents claimed that wildlife has attacked someone they know, of which 76.5% were bear attacks, 18.8% were wolf attacks, and 4.7% were wild boar attacks.

During 2010 and 2014 surveys, university students were surveyed as part of the sampling design and, in general, younger respondents (i.e. university students) and respondents that spent most of their time in urban areas (e.g., shopkeepers, laborers) had more positive attitudes while farmers and shepherds had more negative attitudes towards wildlife (Figures 9 and 10). Knowledge of wildlife ecotourism opportunities increased over time (Figure 11), and while 63.4% of respondents across all years

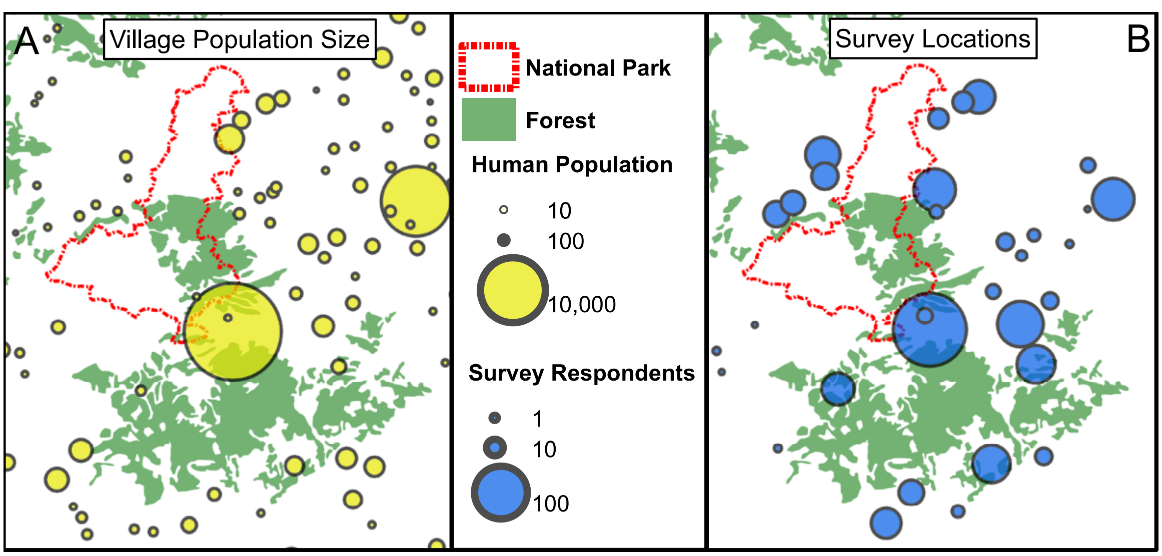

Figure 3. Settlement population size (A) and distribution of opinion surveys (B) conducted in 2006, 2010, and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey.

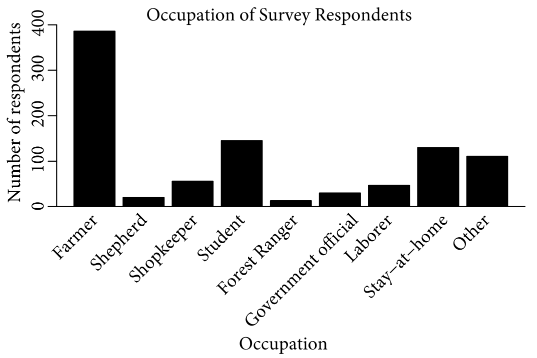

Figure 4. Occupation of survey respondents to a human opinion survey conducted in 2006, 2010, and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. Results are pooled across years.

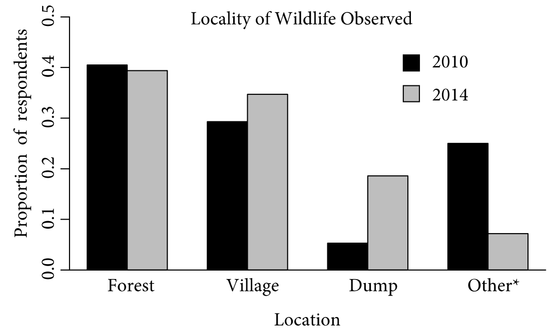

Figure 5. Location where wildlife is most often observed by respondents to a human opinion survey conducted in 2010 and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. *: 'Other' category typically states a specific location in the forest where animals have been observed.

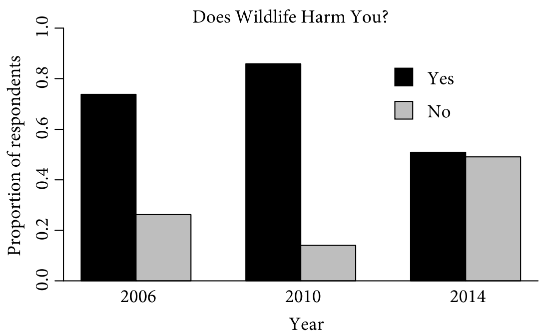

Figure 6. Responses by survey year for the question "Does the wild animal you see harm you?" as part of a human opinion survey conducted in 2006, 2010, and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey.

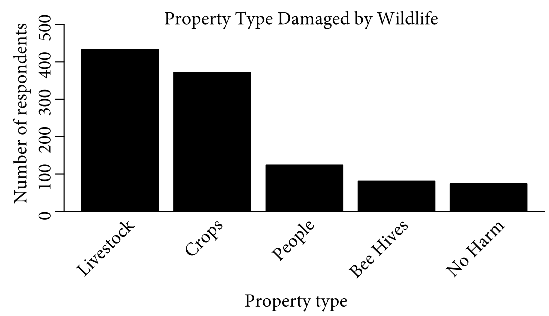

Figure 7. Property damage from wildlife experienced by survey respondents to a human opinion survey conducted in 2006, 2010, and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. Results are pooled across years.

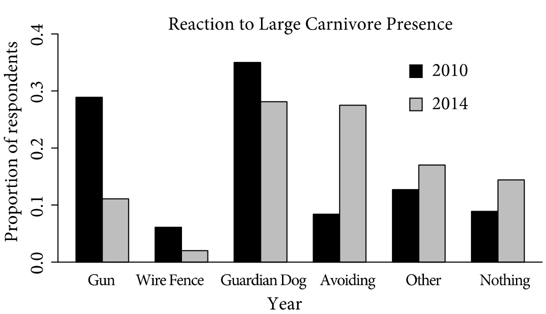

Figure 8. Reaction to large carnivore presence of survey respondents to a human opinion survey conducted in 2010 and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey.

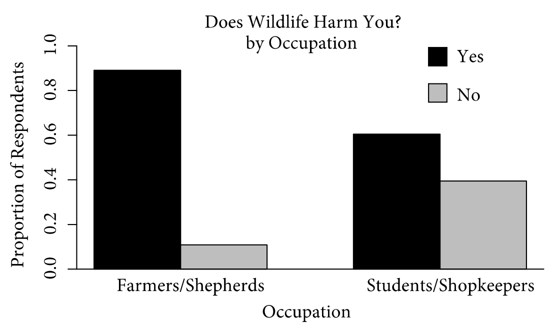

Figure 9. Responses by occupation for the question "Does the wild animal you see harm you?" as part of a human opinion survey conducted in 2010 and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. Results are pooled across years.

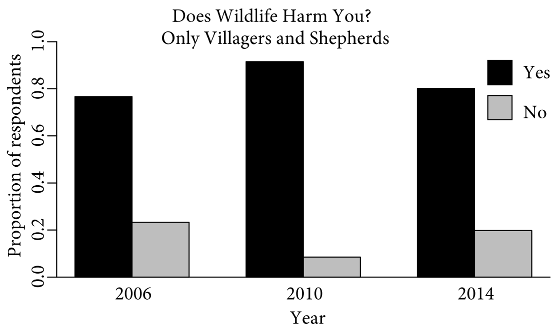

Figure 10. Responses by year for the question "Does the wild animal you see harm you?" as part of a human opinion survey conducted in 2010 and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. Results include only responses from farmers, shepherds, and other occupations that require individuals to be in the forest or agricultural fields.

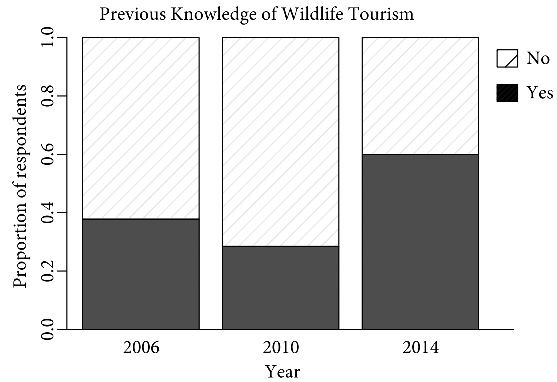

Figure 11. Previous knowledge of ecotourism of survey respondents to a human opinion survey conducted in 2006, 2010, and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey.

had no previous knowledge of wildlife as an ecotourism opportunity, after being informed of this opportunity 76.5% had a desire to participate in future ecotourism opportunities (Figure 12).

4. Discussion

Our results show that in the region of eastern Turkey, conflict between humans and wildlife is occurring and may be a barrier to conservation efforts. The forests in and around the Sarıkamış-Allahuekber Mountains National Park provide habitat for substantial populations of brown bears, gray wolves, and Caucasian lynx (http://newswatch.nationalgeographic.com/2012/02/13/turkeys-first-wildlife-corridor-links-bear-wolf-and-lynx-populations-to-the-caucasus-forests/). The same forests are an important natural resource for adjacent human settlements. Many people in this region use the forests and surrounding meadows as rangelands to support livestock husbandry as the main source of their livelihood. In addition, legal and illegal timber harvesting occurs and a variety of plants are harvested for human consumption or as a food supply for livestock over the long cold winters. Conflict with large carnivores occurs when humans enter forest areas to utilize natural resources and when carnivores encounter human settlements when they leave the forest. Similar occurrences of human–wildlife conflict are likely in many regions of Turkey (Can, 2004; Tuğ, 2005; Ambarlı and Bilgin, 2008), and mitigation programs developed for our study area in eastern Turkey can likely be applied to study areas across the country.

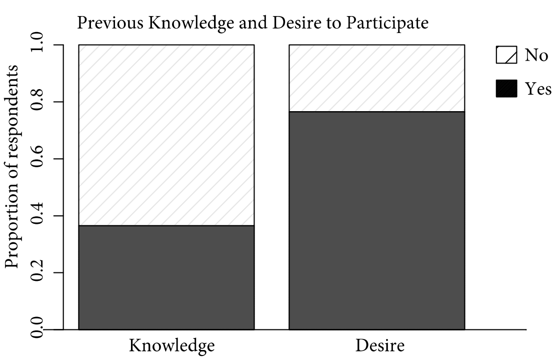

Figure 12. Previous knowledge of wildlife ecotourism and desire to participate in future opportunities of survey respondents to a human opinion survey conducted in 2010 and 2014 in villages surrounding the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey. Results are pooled across the two survey years.

The impact of large carnivores on humans varies greatly; it is species-specific and dependent on regional, local, and human conditions. One well-documented and frequent source of conflict is large carnivore depredation on livestock. Livestock losses can be detrimental, particularly on an individual level and on small-scale livestock husbandry that exists in our study area. In eastern Turkey, damage to livestock and other domestic animals was the most frequent complaint cited by survey respondents, and gray wolves were identified as the most common carnivore to attack livestock. To protect livestock from carnivores, many shepherds use guardian dogs. This traditional system is known to be effective and has been suggested as a solution to modern conservation challenges (Rigg, 2001; Gehring et al., 2010). This is an excellent example of a nonlethal technique to reduce depredation. In eastern Turkey, survey respondents who worked as farmers and shepherds frequently discussed their need for good or better guardian dogs. A subsidized guardian dog program may offer a solution to the problem of poor quality (i.e. mixed breed) guardian dogs.

Guardian dogs are arguably the best nonlethal predatory management technique available and most appropriate for the local conditions in eastern Turkey. However, other technologies exist to prevent livestock loss, including use of fladry (colored flags that deter wolves), electric fences, and range-riders. These techniques are most effective when used together in a holistic approach to reduce encounters with large carnivores. If these approaches can be implemented in eastern Turkey, the next step will be to design and implement a program that will compensate ranchers for livestock losses due to large carnivores. This has been shown to significantly increase tolerance of large carnivores on the landscape (Dickman et al., 2011). However, only ranchers who are actively engaged in nonlethal predatory management techniques would be eligible for a repayment program and trained biologists who can respond to reports of livestock loss are necessary to identify wolf kills versus death from other causes.

In addition to livestock, other agricultural products are also at risk from wildlife. Survey respondents identified "damage to their garden/crops" as the second most common source of conflict; wild boar and bears were identified as the two species that caused the most damage. Specifically, wild boar are reported to frequently dig up crops, gardens, and fields. Wild boar are a common agricultural pest throughout their global range, and one method to lessen their impact is through managed hunting programs (Massei et al., 2015). In Turkey, hunting programs are a potential solution, but more work is needed to increase public interest and create a network of wildlife professionals to monitor and manage wildlife at a local and regional level (Başkaya et al., 2012). Supported by the General Directorate of Nature Conservation and National Parks and Forestry General Directorate of Turkey's Ministry of Forestry and Water Affairs, this network of wildlife biologists would be able to monitor all wildlife and make informed decisions about managing wild boar as a game (i.e. hunted) species. This is a long-term goal but young scientists can be incentivized if more career opportunities are generated by both governmental agencies and nongovernmental organizations.

Brown bears are also causing damage to agricultural products; survey respondents reported that bears are frequently raiding orchards and apiaries. While brown bears are a member of the order Carnivora, they are omnivorous and they forage on a variety of plants, fruits, and berries, and also occasionally on insects, fish, birds, and mammals (Bojarska and Selva, 2012). As such, gardens, orchards, and apiaries located close to forest fragments occupied by bears are at risk of being identified as a food source by bears. Even a single visit by a bear can be extremely detrimental on an individual level to subsistence farmers, which are common in the study area. Human–bear conflict is a well-studied phenomenon and many solutions exist to mitigate conflict. Physical barriers and public outreach have been identified as the most important tools to prevent loss (Can et al., 2014). Importantly, Can et al. (2014) made the central point that conservation of bear species relies on society's ability to tolerate bears, and mitigation of human–bear conflict is important to increase this tolerance and enable the persistence of bear populations.

Bears, wolves, and wild boar can also be seen feeding at the municipal garbage dump located approximately 3 km from the Sarıkamış city center. Based on the authors' ongoing wildlife monitoring projects, this garbage dump represents a major food source for brown bears and a significant food source for gray wolves. Brown bears visit the garbage dump on a nightly basis and 44% of survey respondents identified the garbage dump as a location where they can easily see wildlife. There are frequently 10–15 bears feeding at the garbage dump and up to 33 bears have been observed at a single time (authors' observation). The relationship between garbage dumps and bears has been well-studied and garbage dumps are known to condition bears to human food and humans activity (Peirce and Van Daele, 2006). Human garbage provides foods higher in calories, carbohydrates, and proteins than natural food sources and the hyperphagia capabilities of bears allow individuals to consume large amounts of this abundant food source at once (Stringham, 1989). These nutritional benefits can attract bears to solid waste disposal sites from isolated den sites over 38 km away (Rigg, 2005). As low-quality habitat fragments are often surrounded by human settlements or activity, garbage dumps become ecological traps that pose a variety of threats to both bear and human safety. Primary threats include bears becoming garbage-conditioned (i.e. habituated), leading to increased human–bear conflicts that often result in human injuries and bears killed in control measures (Peirce and Van Daele, 2006). Dangers of dump feeding also include demographic consequences (e.g., altering reproductive rates and body size) as well as juveniles being killed by conspecifics and becoming more vulnerable to poaching and disease transmission (Stringham, 1989). Reducing the conditioning of bears to human food sources is the primary measure to prevent problem bears (Huber et al., 2008). The long-term solution is clearly to close the garbage dump; however, dump closure can subsequently have serious impacts on bears that have become dependent on human refuse as a major food source. In the United States, solid waste management practices and dump closures have resulted in human injuries and subsequent bear kills and will continue to occur (Peirce and Van Daele, 2006). Therefore, understanding the ecology of carnivores in the region (e.g., population size, home range, basic ecology) will inform the management decisions regarding bears using the garbage dump. Addressing the current bears using the garbage dump will be a necessary precursor to dump closure.

All three of the above-mentioned conflicts are generated by the existence of accessible anthropogenic food sources on the landscape. Anthropogenic food sources as resource subsidies for carnivores can lead to demographic and behavioral changes in carnivore populations and subsequent trophic cascades (Newsome et al., 2015). These demographic and behavioral changes translate as increased numbers of large carnivores that are more habituated to human activity. These animals are subsequently less fearful of humans and more likely to approach villages, thus increasing the chance of injury to both humans and wildlife. The high proportion of survey respondents (41.6%) who reported that they themselves or someone they know has been attacked by wildlife is likely related to the availability of human food sources on the landscape. The single most effective preventative measure to reduce human–wildlife conflict in the Sarıkamış forest is to improve general waste management to reduce the availability of human refuse available to large carnivores. This includes changing livestock husbandry practices that allow for livestock waste to be dumped in areas accessible by large carnivores, which will require a change in human behavior.

Changing human behavior will rely on a substantial public outreach campaign to educate the local population about large carnivore presence and ecology in the Sarıkamış forest. Based on survey results, many people are aware of large carnivore presence and some individuals are aware of the ecological services that large carnivores can provide. However, most survey respondents reported that large carnivores negatively impact themselves or their property and generally have a negative opinion about these animals. This suggests that as a conservation organization, KuzeyDoğa will have to focus on providing information to the public that will increase tolerance of large carnivores on the landscape for the conservation efforts to be successful. The majority of survey respondents did not have previous knowledge of wildlife as an ecotourism opportunity, but after discussing the idea of maintaining a healthy forest for tourism, most respondents showed an interest in being involved in future opportunities. This suggests that if conservation efforts provide an economic incentive, it may be possible to increase the local community's tolerance for large carnivores.

Importantly, what we have observed about coexistence of humans and large carnivores in the Sarıkamış forest is representative of many other regions of Turkey and the world. Therefore, we can use the existing solutions to help mitigate human–wildlife conflict (Can et al., 2014). The responses from our survey have identified specific issues that we can address through future community outreach programs, including: 1) providing resources to gain access to high-quality guard dogs, 2) designing and implementing a program to provide payment for livestock losses due to large carnivores, and 3) further educating community members on general ecology and the role of large carnivores in ecosystem function.

Establishing specific conservation objectives is critical for managing a particular species, but large carnivores can also be used as a tool to accomplish a variety of conservation and wildlife management goals. Wide-ranging animals can act as umbrella species; protecting habitat essential for wolves, bears, and lynx will conserve vast areas of habitat that will benefit many other species with smaller ranges (Lambeck, 1997). In 2011, the KuzeyDoğa Society captured gray wolves for the first time in Turkey to deploy GPS tracking collars (http://voices.nationalgeographic.com/2013/12/15/wolves-in-turkey-tracked-for-the-first-time/). Data from these collars demonstrated that wolves had a larger home range than the protected area that existed in the region. These data supported the creation of Turkey's first wildlife corridor, which was designated in 2011 with collaboration between the KuzeyDoğa Society and the General Directorate of Nature Conservation and National Parks and Forestry General Directorate of Turkey's Ministry of Forestry and Water Affairs. The wildlife corridor is designed to promote movement of large carnivores, but it will benefit a wide range of plants and animals, including many species endemic to the region. The ecological importance and charismatic nature of large carnivores also creates an opportunity to use these animals as flagship species for conservation (Walpole and Leader-Williams, 2002). These animals can generate public interest in wildlife management and biodiversity conservation.

4.1. Effects of human–carnivore conflict in Turkey on carnivore conservation

Future conservation and management of large carnivores in Turkey will depend on understanding the perspectives and opinions of local people coexisting with these animals.

Furthermore, management agendas will need to include measures to mitigate current and future human–wildlife conflict. Existing frameworks have been developed to address human–wildlife conflict (Can et al., 2014) and research groups, governmental agencies, and nonprofits have made progress towards coexistence of humans and large carnivores. Our work represents the first large-scale human opinion survey about large carnivores in Turkey and is a contribution to a growing database on quantifying human attitudes towards large carnivores in this region of the world (Dressel et al., 2014).

Our findings are representative of human–wildlife conflict in many other parts of Turkey, particularly in Black Sea regions in the northeast of the country (Ambarlı and Bilgin, 2008). Many survey respondents in our survey and that of Ambarlı and Bilgin (2008) believe that conflicts with bears are increasing over time. This perception of increasing human–wildlife conflict may be a predominant opinion in regions of Turkey where large carnivores and other potentially damaging wildlife species exist. However, in the absence of detailed surveys on a comprehensive spatial and temporal scale, there is no way to determine if negative wildlife encounters are truly increasing. Most importantly, the agricultural-based economy of our study area is likely representative of many other rural areas of Turkey; therefore, our results are indicative of human perceptions of wildlife throughout the country. Our results can be extrapolated to a broader scale; Turkey needs to generate solutions to existing conflict prior to creating a successful wildlife management program that will sustain wildlife as a resource for future generations.

Our survey results show that the largest contributor to human–wildlife conflict is property damage (e.g., livestock and crop damage). One approach needed in Turkey to help mitigate this damage is a compensation program for farmers and shepherds who experience financial loss from large carnivores. This approach has been shown to increase tolerance of large carnivores and decrease poaching and other forms of direct persecution, but each compensation scheme needs to be carefully tailored for a local situation (Dickman et al., 2011). Initially, Turkey needs to assemble a group of experts that can assess large carnivore damage at a regional and local level and subsequently design a system to compensate property owners who are using appropriate nonlethal predator avoidance measures (e.g., guardian dogs, electric fences). This will act as an incentive for local property owners to protect their property with existing technology and ultimately increase acceptance of large carnivore presence on the landscape.

In addition to dedicating a group of experts to address this issue of human–wildlife conflict, Turkey needs to gather information for large carnivores and other wildlife on species distributions, population size, and basic ecology. These data are lacking and could lead to mismanagement of wildlife in the country, such as initiating hunting programs without knowledge of population dynamics of the proposed game animal. In fact, Turkey's General Directorate of Nature Conservation and National Parks has recently taken advantage of the rural perception that negative wildlife encounters are increasing to open brown bears to hunting, despite widespread public opposition (https://www.change.org/p/yaban-hayvanlar%C4%B1-ihale-konusu-olamaz-ihaleyi-durdurun-katliama-son-verin-veyseleroglu) and the lack of reliable scientific data on brown bear populations (http://www.hurriyet.com.tr/kelebek/hayat/29939083.asp). This emphasizes the urgency of establishing a national program on determining large carnivore populations and understanding carnivore ecology using rigorous science, and reducing human–carnivore conflict based on these data.

Turkey is a geographic anomaly, lying at the intersection of three biodiversity hotspots and at the continental confluence of Europe and Asia (Şekercioğlu et al., 2011b). The documented biodiversity across taxa in Turkey is extraordinary and deserves proper conservation and management to ensure use for future generations. Furthermore, Turkey has the unique opportunity to lead the larger region in biodiversity conservation by establishing a group of experts to design and implement a wildlife management plan for the future.

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CHAPTER 7

RECOMMENDATIONS FOR FUTURE CONSERVATION EFFORTS IN HUMAN-DOMINATED LANDSCAPES: THE CASE STUDY OF SARİKAMİŞ

7.1 Abstract

Large carnivores are cryptic and opportunistic species that can inhabit human-modified landscapes at medium-to-high densities without frequent detection. Over the last several decades, several species are rapidly recolonizing large areas in Europe and North America. To properly manage these species in an increasingly dynamic and human-dominated landscape, novel approaches to wildlife conservation and management must be developed. Much research on this issue has been done in developed nations, but more attention needs to be given to vast areas of the developing world that represent hotbeds of global biodiversity. In eastern Anatolia, Sarıkamış-Allahuekber Mountains National Park and surrounding forests is an example of an agrarian landscape dominated by human activity resulting in heavily degraded wildlife habitat. This system may be representative of the majority of existing and potential large carnivore habitat in the world; a long history of human activity has left these areas in a hybrid ecosystem state, one defined by anthropogenic food sources, heavily degraded habitat, and a deficit of wild ungulates and other natural prey species. The condition in eastern Anatolia now sustains a hyperabundance of synanthropic carnivores with no existing plans to monitor

or manage these populations. As a solution, a local environmental nonprofit group—the KuzeyDoğa Society—can provide conservation science to inform conservation and management plans in the region. Environmental organizations such as this are often leading conservation efforts in biodiversity hotspots without long-term funding and receiving little support from government entities. Solutions to large carnivore management in human-dominated landscapes that we provide here can be applied to regions experiencing similar conditions around the world.

7.2 Introduction

The environmental landscape of today is a mosaic of novel ecosystems in a highly altered matrix (Hobbs et al. 2014). Large tracts of intact wildlife habitat are rare; the majority of the earth's surface has been substantially altered, initiating a modern epoch designated as the Anthropocene (Zalasiewicz et al. 2008, Barnosky et al. 2012, Waters et al. 2016). In order to accomplish global and regional conservation goals, biologists and conservationists are beginning to recognize that biodiversity must be studied and managed in human-dominated landscapes (Martin et al. 2014). The next step is to further develop the tools needed to manage individual species and biodiversity as a whole in these landscapes, which means our traditional view of ecosystem structure and species interactions must also change.

Large carnivores represent an ideal focal species to investigate this paradigm shift in conservation and management over time. These species' strong ecological effects through trophic cascades are often mentioned, but the effects of top predators are not well-understood and are under considerable empirical and theoretical scrutiny (Allen et al.

2017). Effects of large carnivores may not be experienced outside of vast expanses of protected areas that are mostly free of human influence (Ripple et al. 2013, Allen et al. 2017). Historically, these animals were heavily persecuted and eradicated throughout much of their range. Currently, they are recolonizing many human-dominated landscapes. Subsequently, as future recolonization and reintroduction occur, we believe populations will become more synanthropic than ever before, and some large carnivore species will help shape novel ecosystem structure and function.

In this paper, we briefly discuss the past and current situation of large carnivore management and conservation and provide a description of potential solutions to the issues surrounding both. As a case study, we focus on the Sarıkamış-Allahuekber Mountains National Park in eastern Turkey, where a comprehensive 4-year large carnivore study has revealed a seemingly novel mammal community structure and synanthropic populations of brown bears, gray wolves, and Eurasian lynx (Chynoweth et al. in prep; Capitani et al. 2016; Cozzi et al. 2016). However, we believe that much of the global range of these species intersects with similar human-dominated agrarian landscapes. The effects of large carnivores on food webs in these human-dominated landscapes is understudied and management suggestions outlined here can be applied to many systems across the globe.

7.2.1 Past Large Carnivore Management Paradigms

Early human-predator relationships were largely shaped by the overall relationship between people and their environment. Hunters and shepherds often had a desire to eradicate large carnivores because of competition for prey, threats to livelihood (e.g., livestock), or human well-being. In Europe, significant declines of bears, wolves and lynx began in the Middle Ages and continued into the 20th century, and eradication was directly caused by persecution and the indirect result of habitat loss. When Europeans colonized North America, they continued this pattern to remove large carnivores. As technology improved and became more readily available, humans were able to lead vast campaigns of large carnivore destruction through government-funded campaigns, using firearms and poison. The results of this paradigm are best observed in North America, where vast wilderness areas (occupied at low densities by Native Americans) were settled in a relatively short time period by Europeans.

First in Europe, then in North America, wildlife management programs moved towards a more science-based approach, taking into account full ecosystems. Consequently, such programs slowly began to include large carnivore species. However, far from being uniform, wildlife management took the form of region-specific and species-specific management plans. Whether these wildlife management plans have positive or negative impacts on carnivore populations depends on the range of stakeholders' experiences and entrenched views on the impact of large carnivores. Over the last 50 years, attitudes have gradually changed, generally moving away from supporting predator extermination and toward supporting predator conservation. In some regions, these societal changes have facilitated megafauna comebacks.

The historically intensive removal of predators was accompanied by broad-scale modification of landscapes including habitat destruction, removal of other plant and animal species, and disruption of many ecosystem functions. Therefore, the effect of large carnivore removal on ecosystems is somewhat unclear. It is a complex question for ecologists, and the paucity of data leaves many of these questions unanswered or with answers that are controversial (Wallach et al. 2015, Ripple et al. 2016, Allen et al. 2017). Many examples from relatively pristine systems, most famously the Greater Yellowstone Ecosystem, suggest that large carnivore removal can result in over abundance of herbivores, subsequent loss of vegetation and loss of critical ecosystem function (Ripple and Beschta 2007). However, large carnivores are inherently difficult to study with a rigorous experimental design given their natural rarity, long generation time, and wide ranges. These factors contribute to a lack of long-term and experimentally-sound studies, which make it very challenging to test ecological hypotheses (Ripple et al. 2014b).

In order to successfully move forward with our carnivore management plans, it is important to acknowledge that we no longer live in a natural world, and large carnivores are not the only species impacted by human domination of the world's ecosystems. Humans have modified chemical cycles, caused global climate change, and created a new geologic epoch based on the high impact of our activity. Just as systems differ depending on human activity, the effects of large carnivores will largely depend on the state of the ecosystem they occupy, as well as the types of human activity in that system (Haswell et al. 2017).

7.2.2 Contemporary Large Carnivore Recovery and Persistence

In the wake of this new wildlife management paradigm and after the creation of the new field of conservation biology, several regions of the world have experienced large carnivore recovery. This remains a polarizing issue, as opponents of large carnivore recovery maintain attitudes described above, but support for large carnivore recovery grows, in part because large carnivores are considered to be some of the world's most charismatic species. The threat of losing some species at the local or even global level has generated interest from government and private groups to create legislation and enact management plans to conserve these species. Subsequently, over the last several decades, large carnivores have recovered or persisted in some landscapes around the world.

One of the best and most well-studied examples is the reintroduction of gray wolves to Yellowstone National Park, USA (Smith and Bangs 2009). Here is an example of one of the largest expanses of protected intact habitat in North America with a near full assemblage of species across trophic levels. Reintroduction of wolves has been reported to alter ecosystem structure through such ecological principles as *mesopredator release hypothesis, trophic cascade hypothesis,* and *behavior-meditiated trophic cascade hypothesis* (Ripple and Beschta 2004, 2007, Ripple et al. 2014a). These results are somewhat controversial (Beschta et al. 2014, Winnie 2014), however, and the authors have been criticized for a failure to evaluate alternative hypotheses (Allen et al. 2017). Much attention has been given to the Yellowstone wolf reintroduction project, though it may promote unwarranted support and justification of reintroduction of large carnivores for ecosystem restoration.

Europe has also experienced a remarkable recovery of large carnivores (Chapron et al. 2014), mainly as a result of natural recolonizations, but also through managed reintroductions. Conservation success of large carnivores in Europe is largely due to protective legislation and increasing social carrying capacity through influencing public opinion (Chapron et al. 2014). The most important result from these activities is the widespread acceptance of the idea that large carnivores and people can coexist on the same landscape (Lopez-Bao et al. 2015).

Whether recovery has been intentional through planned reintroduction (e.g., Yellowstone), occurred naturally through recolonization (e.g., Western Europe), or species have persisted as in Sarıkamış Forest, proponents of large carnivore recovery in our contemporary society typically have three main goals: (*i*) maintaining stable carnivore populations, (*ii*) preventing conflict with carnivores (e.g., property damage and competition over game), and (*iii*) building public support for carnivore conservation. These are the goals our proposed management solutions will strive to achieve in human-dominated ecosystems.

7.2.3 Large Carnivore Recovery in Human-Dominated Ecosystems

Historically, large carnivore management and conservation has been driven by human needs and desires with little impetus to incorporate ecological information into the decision making process. As the effect of large carnivores continues to be debated, carnivores themselves are recolonizing human-dominated landscapes, and humans are interacting with these species for the first time in novel ecosystems. Conservation of large carnivores faces a new set of challenges in the Anthropocene. The combination of human population growth and expanding human ecological footprint has resulted in the destruction and degradation of wildlife habitat and subsequently, a global decline of species. Though many large carnivore species are highly intelligent and adaptable, those that are able to exploit anthropogenic food resources and use synanthropic behavior to increase fitness are more likely to recover in human-dominated ecosystems than species that do not. Generalist synanthropic species, such as gray wolves and brown bears, are most likely to be successful in these novel ecosystems. However, they are the exception. Currently, of the 295 species of mammal carnivores, 115 species are extinction-prone (extinct, threatened or near threatened with extinction), and most of these are small, tropical specialists (IUCN 2016).

7.2.4 Coexistence with Large Carnivores

It is often a challenge for people to co-exist with large carnivores because of competition for prey, threats to livelihood (e.g., livestock), or to human well-being. Of course, these factors are the driving force behind persecution of these animals. As such, the field of conservation biology has recently been interested in the question of coexistence of humans and large carnivores on the same landscape (Bergstrom 2017). Advances in technology and field methods, as well as increased human-wildlife conflict due to increasing human population and habitat encroachment, has stimulated more research focused on this topic.

At broad scales, it may appear that humans and large carnivores are not able to regularly use the same locations. Life history traits (e.g., high resource requirement) and human-carnivore conflict has steered large carnivore conservation towards establishing and expanding protected habitat (i.e., protected areas) with low densities of human settlements (Mills 1991, Mech 1996). These protected areas provide resources and space while reducing the likelihood of human-carnivore conflict. But Anthropocene conditions may limit the capability of conservationists to designate large protected areas that satisfy the traditional requirements of large carnivores.

At fine spatial scales, some carnivore species are able to coexist in human dominated landscapes. Generalist carnivores of lower body mass are frequently observed in urban and suburban environments (Gehrt et al. 2010) and large-bodied carnivores such as cougars, coyotes, wolves, and bears are also known to be synanthropic. For example, studies of diel scale activity patterns have demonstrated that tigers and humans can coexist (Carter et al. 2012) and that cougars can use riparian corridors to navigate through high-density human settlements (Dickson et al. 2005)

In many examples of human-carnivore coexistence, co-adaption (both humans and carnivore change their behavior) has been suggested as a critical component for successful coexistence (Carter and Linnell 2016). Carnivores have been observed changing diets, movement patterns, and range size in response to human presence, but in order for coexistence to occur, humans also need to adapt to the presence of large carnivores. This may involve accepting a tolerable level of risk to increase social carrying capacity enough to ensure long-term carnivore population persistence (Carter and Linnell 2016).

As evidence of successful human-carnivore coexistence grows, some conservationists ask the question whether intact wilderness is necessary for these species. To be clear, there is no doubt that protected areas are vitally important to conserve some elements of biodiversity, especially for habitat specialists that make up the majority of species in many ecosystems; however, these ideas have been debated (Lopez-Bao et al. 2015), and studies suggest that for some species of large carnivores, large tracts of protected area are not necessary (Lopez-Bao et al. 2015). Instead, human-carnivore coexistence may be a requisite for some species of large carnivores to persist in the Anthropocene.

7.3 Large Carnivore Management in Sarıkamış-Allahuekber Mountains National Park in the Caucasus Global Biodiversity Hotspot

An example of large carnivores persisting in a human-dominated landscape is the Sarıkamış-Allahuekber Mountains National Park in Northeastern Turkey. Here, we have observed a hyperabundance of large carnivores in the absence of a significant natural prey base (Chynoweth et al. in prep) coexisting with humans in an agrarian landscape and relying on anthropogenic food sources (Capitani et al. 2016, Cozzi et al. 2016). Wildlife resources are largely left unmanaged, and to our knowledge, few data have been collected for natural resources in the region (Ambarlı et al. 2016). Moving forward, a large carnivore management plan will ensure that large populations of bears, wolves, and lynx will persist, and biodiversity as a whole will be conserved. The goal of this management plan will be to effectively monitor biodiversity in the area and reduce human-wildlife conflict to ensure the persistence of large carnivores.

Large carnivores are charismatic species, but due to their magnified potential impacts on rural communities, management and conservation of large carnivores in such areas represent a special challenge. While damage to livestock and crops, competition with hunters, and threats to human safety are historical problems for people living in urban and suburban areas, these concerns are a reality for many rural populations that currently coexist with these animals. In Sarıkamış, human-wildlife conflict is well documented (Chynoweth et al. 2016), but few solutions currently exist. In order to be successful, the management of large carnivores here must include community involvement and needs to emphasize tolerance of large carnivore presence by society. Furthermore, management strategies must be based on scientific data regarding population status and dynamics, ecology, and interaction with other species and humans.

Established in 2007 by Dr. Çağan Şekercioğlu, the KuzeyDoğa Society is a volunteer-based environmental nonprofit, nongovernmental organization (NGO) based in Kars, Turkey and poised to make critical contributions to a large carnivore conservation plan in Sarıkamış (Akkucuk and Sekercioglu 2016). As a local organization, KuzeyDoğa Society has a positive reputation in the region and importantly, is able to work with local communities to achieve conservation goals. Overall goals for large carnivore conservation in Sarıkamış will be to reduce human-wildlife conflict, increase social carrying capacity of large carnivore presence, and conserve biodiversity in the immediate area.

The single biggest challenge to conserving biodiversity in Sarıkamış and the broader region will be effectively managing human activity. If legislation protecting biodiversity is implemented, substantial financial resources will be needed to generate paid positions for individuals to monitor biodiversity and enforce regulations related to land use and resource extraction. KuzeyDoğa Society has a small existing infrastructure that can be built upon to accommodate additional positions within the organization. In order to maintain local support, any resource management plan, legislation, or law enforcement must allow for local villagers to continue nondestructive land uses and therefore KuzeyDoğa Society is in a good position as an established regional NGO that is recognized locally for benefiting local communities through their past work (Akkucuk and Sekercioglu 2016).

7.3.1 Ecological Restoration

The unique trophic structure and limited availability of resources in Sarıkamış will shape the plans to restore ecosystem function. Following main paradigms in restoration ecology, the goal of restoration will be to foster an ecosystem that is resilient and self-sustaining while supporting sustainable resources use by communities (Hobbs and Norton 1996). Efforts to restore ecological function in Sarıkamış will be focused on limiting human use of priority areas and reintroductions of native ungulates. There is no baseline ecosystem condition which these efforts are trying to restore.

7.3.1.1 Habitat Restoration

Habitat restoration in Sarıkamış should focus primarily on limiting human use and resource extraction in areas identified as critical habitat for large carnivores. Large-scale vegetation restoration is unlikely in the region due to cost, as well as limited expertise and materials. Areas that have been identified as critical habitat (See Chapter 4 of this dissertation) are representative of the entire Sarıkamış Forest, ranging in elevation, geology, and vegetation. In the absence of intense human activity (e.g., livestock grazing), vegetation would gradually be restored, increasing habitat quality for all three target carnivore species, as well as providing critical resources for other wildlife and plant species in the region.

A key component of habitat restoration will be designating and maintaining strict nature reserves and wilderness areas. This will be a significant challenge given the complex socio-political condition in the region; however, most land in Turkey is under the ownership and authority of the state. Therefore, designation of legally protected areas can be seen as the principal tool in biodiversity conservation. A network of protected areas currently exists in Turkey, with 14 different types of protected areas across the country covering 7.2% of the country (Ambarlı et al. 2016), which includes Sarıkamış-Allahuekber Mountains National Park (SAMNP). However, as seen in SAMNP, protected area status is not equivalent to measurable success conserving biodiversity.

By designating several types of protected areas in Sarıkamış, biodiversity can be conserved, and local communities can continue to utilize forest resources. Chapter 4 of this dissertation identifies the most suitable habitat for large carnivores in the region. Ideally, this area will be given protected area status which could fall into one (or more) of several categories. The best-case scenario would be to designate a portion of this area as a strict nature reserve (IUCN Category Ia) buffered by wilderness areas (IUCN Category Ib) or a matrix of habitat/species management areas (IUCN Category IV) and protected areas with sustainable use of natural resources (IUCN Category VI).

The role of KuzeyDoğa Society is this process will primarily be as an advocacy group raising public awareness and lobbying for political support of legislation for protected area designation. The NGO has demonstrated their effectiveness at this process by creating eastern Turkey's first Ramsar wetland, designating Turkey's first wildlife corridor, connecting SAMNP to the larger, more intact forests of the Black Sea region (Şekercioğlu 2012) and promoting the "Save the Aras River Bird Paradise" campaign aimed to halt the planned Tuzluca Dam project on the Aras river through a change.org campaign (Akkucuk and Sekercioglu 2016).

7.3.1.2 Reintroduction of Native Prey Species

The hyperabundance of large carnivores, lack of natural prey, and synanthropic behavior of wildlife directs restoration efforts towards the reintroduction of native ungulates into the system. Second only to designating new protected areas, this should be prioritized as a realistic short-term restoration goal in Sarıkamış Forest and SAMNP. Planned reintroductions of ungulates would have two goals: (*i*) reduce wolf depredation on livestock and (*ii*) restore native browsing ungulates on the landscape. Red deer (*Cervus elaphus*) is a potential candidate species especially with existing red deer reintroduction efforts in Turkey, but roe deer (*Capreolus capreolus*) is the most suitable candidate species for reintroduction based on several factors. Roe deer is an important prey species of wolves and lynx in many other parts of their range (Jędrzejewski et al. 1993, Mattioli et al. 2004). Roe deer have been successfully reintroduced in many other parts of the world, with detailed protocols available on reintroduction logistics (Calenge et al. 2005, Torres et al. 2016). Lastly, while roe deer are functionally extinct in Sarıkamış Forest, they have been captured rarely on camera traps and populations are known to exist in the broader region (Chynoweth et al. in prep).

Successful roe deer reintroduction would fill a critical void in available natural prey species for lynx and wolves, two species that prey on livestock and are the source of human-wildlife conflict in the region (Chynoweth et al. 2016, Capitani et al. 2016). In other systems, when wild prey species are present, wolves will preferentially hunt wild ungulates (Imbert et al. 2016, Newsome et al. 2016) and even a small population of native ungulate reintroductions could facilitate wolves' switch to primarily wild ungulate diet (Meriggi and Lovari 1996). Combined with effective damage prevention measures outlined in the following section, human-wildlife conflict would likely decrease as natural prey populations became reestablished.

Reintroduction of roe deer will also likely benefit overall habitat restoration efforts in Sarıkamış by restoring important ecosystem effects, such as impacts on primary production, nutrient cycling, disturbance regimes, habitat heterogeneity, and seed dispersal (Hobbs 1996, Svenning et al. 2016). Importantly, a comprehensive ungulate reintroduction program would create opportunities to test important hypotheses in restoration ecology and the science of species reintroductions (Armstrong and Seddon 2008, Seddon et al. 2014).

Reintroduction programs would best be initiated by the Ministry of Forestry and Water Affairs and the General Directorate of Nature Conservation and National Parks but KuzeyDoğa Society can contribute to reintroduction of wild ungulates in several ways based on their experience tagging and monitoring large carnivores in Sarıkamış forest. Given their knowledge of the region, the NGO can determine proper release locations and lead the long-term monitoring of released ungulates to determine the success of the program. KuzeyDoğa Society has been working for over 10 years with large carnivores and the local community in Sarıkamış, qualifying them to assess the impact of ungulate reintroduction on carnivore ecology and conservation.

Establishing a self-sustaining population of native ungulates will also benefit local communities by providing legal hunting opportunities for residents. Sarıkamış is a rural, agrarian system with a population of people who regularly harvest forest products for sustenance (Chynoweth, pers observation). Hunting in Turkey is strictly enforced through the Terrestrial Hunting Law; however, illegal hunting is still a major cause of population declines throughout the region (Ambarlı et al. 2016). By reintroducing, monitoring, and actively managing a roe deer population in Sarıkamış, residents can eventually be introduced to and participate in an adaptive harvest management plan. Tourism already plays an important role in Sarıkamış' economy (skiing) with existing infrastructure for tourists; in the future, ungulate populations could generate income for local people through hunting tourism, which currently exists in Turkey at low levels.

7.3.2 Human-Wildlife Conflict

Human-wildlife conflict is a well-known and intensely examined topic in the field of large carnivore ecology and conservation. Typically, conflict arises when an animal poses a direct and recurring threat to the livelihood or safety of humans or their property. The impact of carnivore losses can be devastating for an individual or family, even if they appear small at the community level (Hill 2004). Globally, the frequency and costs of conflicts are increasing, likely due to growing human populations and ingress of humans into wildlife habitat (Treves and Karanth 2003). These conflicts often lead to the direct and indirect persecution of carnivores, which can lead to population declines or alteration of animal behavior (Ordiz et al. 2013).

Public opinion of wildlife species—especially large carnivores—is a critical component in their management and conservation. Human dimensions of wildlife management have thus become a growing field of research with the goal of facilitating a level of human-wildlife coexistence that allows wildlife populations to persist (Madden 2004). Conflict can increase when the interests of local people are not included in management plans, or these people are not empowered to find their own solutions. If the economic and social well-being of local communities is not considered, local support for conservation diminishes, and long-term goals and priorities of conservationists are not met. Therefore, identifying, communicating, and collaborating with stakeholders is essential to conservation of large carnivores, especially outside protected area boundaries (Treves et al. 2006).

In Sarıkamış, our multiyear community opinion surveys have revealed human-wildlife conflict to be a critical barrier to large carnivore management and conservation (Chynoweth et al. 2016). Similar to other agrarian systems throughout the world, animal husbandry and farming are significant drivers of the economy. Consequently, livestock depredation and crop damage represents one of the biggest generators of conflict. In order to facilitate successful mitigation, multiple and adaptable tools are required (Madden 2004). KuzeyDoğa Society stands to make the largest contribution to large carnivore conservation by working with the local community to implement mitigation strategies. In the sections below, we outline some key tools the NGO can use to alleviate human-wildlife conflict in Sarıkamış.

7.3.3 Tools to Prevent Human-Wildlife Conflict

Each of the target species has varying responsiveness to tools for reducing conflict and limiting persecution of large carnivores, with some tools equally effective for all species. The most effective approach for conservation of all three species will be to incorporate multiple tools into a comprehensive human-carnivore conflict management plan. Given appropriate financial support, KuzeyDoğa Society could effectively manage all mitigation programs by hiring additional full-time staff and become a leader in reducing human-wildlife conflict and increasing carnivore tolerance in the region.

Ultimately, a livestock damage compensation program would be most appropriate for the region, a technique known to increase tolerance of large carnivores on the landscape (Dickman et al. 2011). Several prerequisites are necessary to make this program operational. Most important, funding must be made available to supply this program with the necessary funds to compensate for livestock loss. Second, an expert in large carnivore depredation is an absolute necessity for the program. This individual must be properly trained and willing to train others in the community. Finally, cooperation from livestock owners and farmers who agree to be actively engaged in other nonlethal predatory management techniques and would be required to report livestock loss within 24 hours. KuzeyDoğa Society could manage this compensation program while providing expertise in identifying carnivore depredation.

Another important tool to reduce human-wildlife conflict in Sarıkamış is to increase the quality of guardian dogs. This was the most common response from community members when they were asked what they needed to protect their livestock (Chynoweth et al. 2016). Most shepherds in the region currently use guardian dogs, but many state that they do not have access to effective dogs, nor the resources to care for dogs properly (e.g., proper food and veterinary care). Guardian dogs have a long history in Turkey and numerous existing groups have access to high quality dogs (Yilmaz et al. 2015). KuzeyDoğa Society could partner with existing dog breeders in other regions and local farmers to establish a dog training and breeding facility in Sarıkamış to produce high quality guardian dogs at subsidized prices for local shepherds.

In addition to livestock damage compensation and increasing access to guardian dogs, a suite of other nonlethal techniques exist to reduce human-wildlife conflict from livestock losses (reviewed in Cluff & Murray 1992; Bangs & Shivik 2001; Rigg 2001; Sillero-Subiri & Laurenson 2001; Rigg et al. 2011; Can et al. 2014; Stone et al. 2017). These include separating livestock and carnivores with a physical barrier (e.g., fencing, avoiding dangerous areas, livestock in pens at night), discouraging predators (e.g., electric fences, flandry, turbo flandry, spotlights, klaxon, radioactivated guardbox) and protecting livestock (e.g., guarding animals, harassing, nonlethal/blank ammunition, fitting protective collars). All or some of these nonlethal approaches can organized and distributed to livestock owners by KuzeyDoğa Society as a prerequisite to gaining access to more formal programs such as livestock compensation and access to guardian dogs.

Lethal techniques for large carnivore management are routinely used throughout the world, but should represent the last possible option after all nonlethal techniques have been exhausted (Naughton-Treves and Treves 2005). Recent work demonstrates that nonlethal techniques are more effective than lethal techniques and that lethal techniques may actually be counter-productive (Stone et al. 2017). Such steps as direct persecution (e.g., poison, weapons) can result in unstable populations of these animals, which can lead to atypical behaviors, such as relying more heavily on anthropogenic food sources such as livestock (Naughton-Treves and Treves 2005). For example, the disruption of social structure in wolf packs may increase livestock depredation (Imbert et al. 2016).

7.3.4 Waste Management

Waste management is the single most important factor in conservation and management of large carnivores in Sarıkamış. The impact of the large, open sky, unmanaged municipal garbage dump here is well-known (Cozzi et al. 2016; Chapter 4). Garbage dumps are widely known to cause habituation of animals. Food-conditioned bears increase human-wildlife conflict and reduce the social carrying capacity for large carnivores on the landscape. For successful conservation management to occur, a plan to close the garbage dump must be initiated and must include methods to accommodate habituated bears, which may include a supplementary feeding program.

While the municipal garbage dump presents the most glaring issue, food-conditioned bears are present across the entire study area and have been recorded raiding dumpsters at hotels and picnic sites (Chynoweth, pers obs). Proper disposal of human refuse (garbage, potential food) at smaller sites in bear-proof dumpsters would help alleviate human-wildlife conflict and prevent new generations of bears from becoming food-conditioned. Presence of these bear-proof dumpsters would also help educate the local community about habituated bears, and provide a clear solution.

Successful waste management also necessitates the proper disposal of livestock waste (i.e., carcasses). Livestock husbandry is a major component of the local economy, and there are currently no known government regulations regarding disposal of carcasses. Livestock losses that occur while moving herds from one location to another are left behind, and remains from livestock processing plants are dumped at the municipal garbage dump. If these conditions persist, conflict at these disposal locations is inevitable, since people are inadvertently baiting carnivores in these areas frequented by humans.

7.3.5 Building Local Capacity and Increasing Social Carrying Capacity for Large Carnivore Conservation

The local community in Sarıkamış is one of the most important components to success of a large carnivore conservation program. If social acceptance of large carnivores is low, populations will decline regardless of efforts from biologists to protect habitat or species. One approach to increase social carrying capacity is to involve community members in active research and natural resource management through citizen science and employment. This will encourage people to take ownership of natural resources and thus develop a need to contribute to conservation efforts.

Citizen science opportunities for large carnivore management should focus on setting up a broad scale camera trapping effort throughout Sarıkamış forest. Citizen science camera trapping has proven successful in many other areas, and several procedures are available to train community members in camera deployment and data management (McShea et al. 2016, Forrester et al. 2016). By incorporating local people in camera trapping, two main goals would be accomplished. First, and most important, people would learn about the presence and importance of local biodiversity and conservation goals for the area. Second, if properly executed, community members could operate a complete camera-trapping monitoring program, which is an important component for the overall carnivore management plan in Sarıkamış. Also, by learning about camera traps and the reason this equipment is used, we can hope that there would be a decline in the rates of theft, which was a critical barrier in our own work. This citizen science effort would create advocates for mammal conservation and for the organizations facilitating biodiversity conservation (Forrester et al. 2016).

Another opportunity to build local capacity is to train individuals to conduct community opinion surveys to understand local perspectives of large carnivores in an effort to reduce human-wildlife conflict. Previous efforts in Sarıkamış suggest that people are very willing to participate in these surveys; however, foreign survey administrators were concerned that responses may not be unbiased as villagers were reluctant to share sensitive or incriminating information with outsiders (Chynoweth et al. 2016), By employing local people to conduct surveys, our results would be less biased and more informative.

A major component of this work needs to focus on education and outreach to communicate to the local community the importance of biodiversity and of increasing social carrying capacity of large carnivores in Sarıkamış. The KuzeyDoğa Society has led a few small outreach programs in the region, all of which have been well received. Still more programs need to be implemented to reach people in small villages on the edges of critical habitat. These are the people that likely have the most interaction with large carnivores. Through outreach programs, the KuzeyDoğa Society will become a leader in large carnivore conservation in the broader region and deepen their relationship with the local community as an organization bringing social and economic benefits to the area. As such, facilitating the management approaches described here will become more efficient and effective.

7.4 Conclusions

At first glance, the situation in Sarıkamış appears to be somewhat unique in terms of mammal community structure, large carnivore hyperabundance, and degree of synanthropic behavior. But the reality is that these conditions may be more common than previously thought, and may become more common in the future. Sarıkamış Forest is a combination of human encroachment on natural habitat, temperate agrarian system, poor socioeconomic conditions, and being understudied by biologists. How many places like this exist in the world? Are generalist carnivores exhibiting the same behavior?

I have had many conversations at academic conferences and with collaborators in an effort to seek out systems with similar parameters and ask the question, “Is Sarıkamış unique, or do other places exist with similar conditions?” Anecdotally, other researchers have shared similar experiences, but rarely have data to share regarding mammal community structure or human-carnivore interactions. In the future, I predict that more systems reflecting conditions in Sarıkamış Forest will be uncovered as generalist predators continue to persist or recover in human-dominated landscapes.

Wildlife on our planet is increasingly living out their lives in human-altered landscapes that are continuously threatened by chemical inputs, human activity, and habitat loss. In addition to losing the intrinsic value of biodiversity, humans are also losing the ecosystems services that provide purification processes, pollination of crops, and other critical ecosystem services. Globally, we also know that large carnivore populations are declining and threatened by human activity (Ripple et al. 2014b). Complicating conservation efforts is the fact that the effect of large carnivores on these systems is still largely unknown but often sensationalized (Allen et al. 2017). To alleviate pressures on large carnivores and biodiversity in general in systems such as Sarıkamış, we have identified the management recommendations described above, focused on restoring ecological function, reducing human-wildlife conflict, and increasing social carrying capacity.

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APPENDIX A

CONSERVATION OF A NEW BREEDING POPULATION

OF CAUCASIAN LYNX (*LYNX LYNX DINNIKI*)

IN EASTERN TURKEY

Chynoweth, M. W., E. Çoban, and Ç. H. Şekercioğlu. 2015. Conservation of a new breeding population of Caucasian lynx (*Lynx lynx dinniki*) in eastern Turkey. Turkish Journal of Zoology 39:1–3. Reprinted with permission from the Scientific and Technological Research Council of Turkey

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Short Communication

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Conservation of a new breeding population of Caucasian lynx (*Lynx lynx dinniki*) in eastern Turkey

Mark W. CHYNOWETH[1,*], Emrah ÇOBAN[2], Çağan H. ŞEKERCIOĞLU[1,2,3]
[1]Department of Biology, University of Utah, Salt Lake City, UT, USA
[2]KuzeyDoğa Society, Kars, Turkey
[3]College of Sciences, Koç University, Rumelifeneri, Sarıyer, İstanbul, Turkey

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Abstract: Current data on the distribution and ecology of the Eurasian lynx (*Lynx lynx*) in Turkey are limited. Furthermore, lynx in the Caucasus region are likely to represent a subspecies of the Eurasian lynx, the Caucasian lynx (*L. l. dinniki*). Throughout its range, lynx increasingly face threats due to human activity, with habitat loss and prey depletion being of particular concern in eastern Turkey. As part of our camera trapping efforts to monitor large carnivores in the Sarıkamış-Allahuekber National Park and surrounding forests in Kars and Erzurum provinces, eastern Turkey, we have documented a breeding population of Caucasian lynx outside the species' published range. In addition to the threats above, vehicle strikes, poaching, and guardian dogs also threaten this small population. There is an urgent need for ecological research, awareness raising, and community-based conservation efforts focused on large carnivores in the region.

Key words: Anatolia, camera trapping, carnivore, cats, Caucasus biodiversity hotspot, human–wildlife conflict, threatened species

The Eurasian lynx (*Lynx lynx*) is a widely distributed species in Asia and Europe, relying on adequate forest cover and a sufficient prey base for its survival (Aulagnier et al., 2009). Historically, lynx inhabited a much larger region including many areas throughout western Europe; however, habitat loss and human activity has fragmented the population into isolated remnants in many parts of its range and some isolated European subpopulations are critically endangered or endangered (Breitenmoser et al., 2008). While lynx have been successfully reintroduced to several areas of central and western Europe (Kaczensky et al., 2013), habitat availability and human–carnivore conflict continue to be critical barriers to their success in many areas. As a result, habitat constraints and limited connectivity between Eurasian lynx populations have resulted in high levels of genetic differentiation in parts of their western range (Ratkiewicz et al., 2012). In some cases, isolated populations have been recognized as subspecies of lynx, leading to the designation of discrete, demographically independent populations. The lynx in eastern Turkey are considered a subspecies of Eurasian lynx known as the Caucasian lynx, *Lynx lynx dinniki* (von Arx et al., 2004; Albayrak, 2012), are considered endangered (Price, 2000), and are in need of a conservation-breeding program (von Arx et al., 2004).

For a temperate region, Turkey has an impressive assemblage of large mammalian carnivores, including lynx, caracal (*Caracal caracal schmitzi*), leopard (*Panthera pardus tulliana*), Eurasian brown bear (*Ursus arctos arctos*), gray wolf (*Canis lupus lupus*), and striped hyena (*Hyaena hyaena*), with Persian lion (*Felis leo persica*), tiger (*Panthera tigris virgata*), and Asiatic cheetah (*Acinonyx jubatus venaticus*) having gone extinct in the past two centuries (Şekercioğlu et al., 2011a). However, Turkey's biodiversity is in crisis (Şekercioğlu et al., 2011a, 2011b), Turkey's carnivores are understudied, and, illustratively, little is known about the distribution and ecology of lynx in eastern Turkey. These medium-sized cats are elusive animals that are rarely seen in the wild. Recent camera trapping projects and surveys have generated records of lynx in some provinces (Ambarlı et al., 2010; Albayrak, 2012) and neighboring countries in which they had not previously been sighted/recorded (Moqanaki et al., 2010 and references therein). While the distribution and status of lynx in Turkey are data-deficient, we think that the fragmentation of forest, depletion of prey base, poaching, and vehicle collisions represent significant threats to this understudied subspecies. Due to its geographic isolation, the population of *L. l. dinniki* in eastern Turkey could potentially represent an evolutionarily significant unit in need of detailed research (Moritz, 1994).

* Correspondence: chynoweth.mark@gmail.com

Since 2006, our camera trapping study has been operational in the Sarıkamış-Allahuekber Mountains National Park and surrounding forests in eastern Turkey's Kars Province. Forest cover on this high elevation plateau is dominated by Scots pine (*Pinus sylvestris* var. *hamata*), but it is extremely fragmented due to human agricultural activity. Legal logging occurs on about 85% of the ~328 km^2 forest and illegal timber poaching is widespread (Şekercioğlu, 2012). Most notably, our study site is located more than 100 km from the nearest lynx locality in the IUCN Red List distribution map (Breitenmoser et al., 2008; Figure 1). Our camera trap survey has documented 15 mammal species, including the Caucasian lynx. Regular photographs of lynx from 9 months of the year provide concrete evidence to expand the known distribution of lynx in Turkey. Several of our photos document lynx with cubs, the first photographic evidence of a breeding population of lynx in the area (Figure 2a). In our most recent survey with 13 camera traps over approximately 3 months (1351 trap-nights), we had 8 instances of 5 distinct individuals recognized by unique pelage.

Our discovery suggests that the Sarıkamış-Allahuekber National Park and the surrounding forest is a refuge for predators in a highly fragmented landscape dominated by human activity. Therefore, protecting these forests and connecting them to the bigger forests in the north with Turkey's first wildlife corridor (Şekercioğlu, 2012) are of vital importance to the conservation of large carnivore populations, including the Caucasian lynx and other feline species. In 2010, our camera trap survey documented

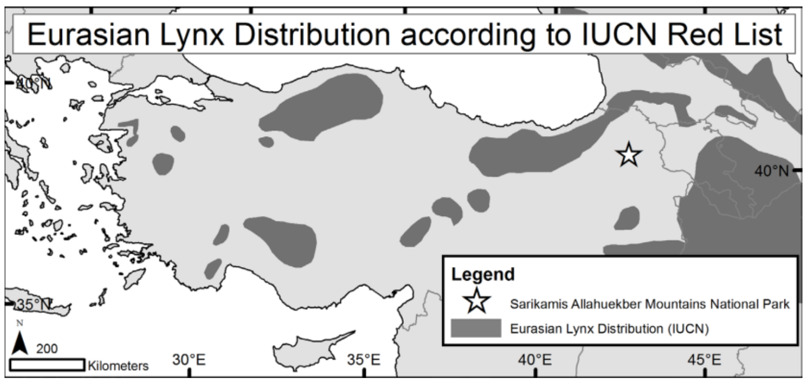

Figure 1. IUCN distribution of Eurasian lynx (*Lynx lynx*) in Turkey shaded in black with the Sarıkamış-Allahuekber Mountains National Park represented with a white star (Breitenmoser et al., 2008). KuzeyDoğa's work focuses on the national park and surrounding areas, where we have documented a breeding population of lynx.

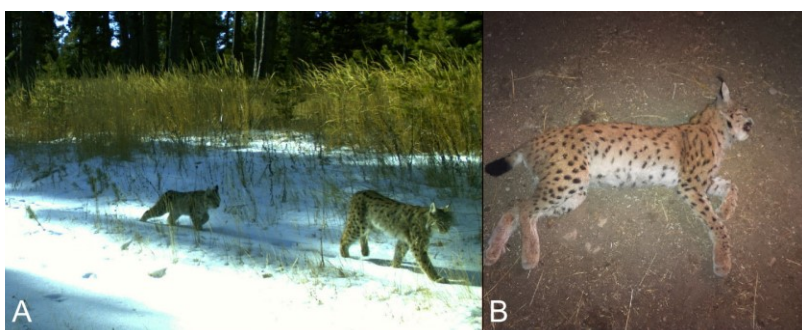

Figure 2. (A) Camera trap photo from the KuzeyDoğa Society's ongoing camera trap project in eastern Turkey, focusing on the Sarıkamış-Allahuekber Mountains National park and the surrounding forest. This is the first photographic evidence of a breeding lynx population in the area. **(B)** A lynx killed by a vehicle collision in fall 2013.

wild cats (*Felis sylvestris sylvestris*) for the first time in the region. Nearby, the Aras River watershed harbors jungle cats (*Felis chaus chaus*). Leopards have also recently been recorded in all the countries neighboring northeastern Turkey (i.e. Georgia, Armenia, Azerbaijan (Nakhchivan), and Iran (Khorozyan and Abramov, 2007; Ghoddousi et al., 2010)) and may survive in the rugged Arpaçay Canyon and Aras River military zones, which form the Turkey–Armenia border and are off limits to the public.

Like most large carnivores, lynx require large areas and are particularly susceptible to threats directly related to human activity (Ripple et al., 2014). Illegal skin trade has been identified by the IUCN as the biggest threat to the Eurasian lynx, followed by habitat loss and prey depletion (Breitenmoser et al., 2008). In eastern Turkey, all three of these threats exist. However, habitat loss and prey depletion may play a proportionately larger role in limiting lynx populations. Agricultural activities, mainly livestock grazing, are decreasing forest cover, which is necessary for lynx and their prey to survive. In many areas that lynx inhabit, ungulates are considered a primary food source. However, evidence of roe deer from camera trap surveys and scat surveys in the region is extremely rare. Out of 3827 trap nights at 25 camera trap stations in the Sarıkamış forest over 8 years, we documented a maximum of 5 roe deer in only 41 photos. Lynx are also killed regularly in eastern Turkey by vehicle collisions, poaching, and sheep dogs (Figure 2b). A collaboration between the University of Utah and the KuzeyDoğa Society, our wildlife conservation ecology project is being carried out with the hope of contributing to the growing conservation movement in Turkey and improving carnivore conservation in the region. We strongly recommend detailed research on the behavior, distribution, genetics, ecology, and population biology of the Caucasian lynx in eastern Turkey to better understand the geographic range, population trends, and threats to this distinct population of lynx.

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APPENDIX B

WOLF DIET IN AN AGRICULTURAL LANDSCAPE OF NORTHEASTERN TURKEY

Capitani, C., M. Chynoweth, J. Kusak, E. Çoban, and Ç. H. Şekercioğlu. 2016. Wolf diet in an agricultural landscape of north-eastern Turkey. Mammalia 80: 329-334. Reprinted with permission from the De Gruyter.

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Short Note

Claudia Capitani*, Mark Chynoweth, Josip Kusak, Emrah Çoban and Çağan H. Şekercioğlu

Wolf diet in an agricultural landscape of north-eastern Turkey

Abstract: In this study, we investigated wolf feeding ecology in Kars province, north-eastern Turkey, by analysing 72 scat samples collected in spring 2013. Ongoing camera trap surveys suggest that large wild ungulates are exceptionally rare in the region. On the contrary, livestock is abundant. Accordingly, scats analysis revealed that livestock constituted most of the biomass intake for wolves, although small mammals were the most frequent prey items. Wild ungulates were occasional prey, and although wolves make use of the main village garbage dump as a food source, garbage remains were scarce in scat samples. Wolf dependence on anthropogenic resources, primarily livestock, generates human-wildlife conflicts in the study area. Uncontrolled carcass disposal seems to boost this wolf behaviour. Synanthropy enhances the probability of wolf-human encounters and thus increases the risk of direct persecution, vehicle collisions, and hybridisation with dogs. When livestock is not available, small mammals are an important alternative prey for wolves. This may increase interspecific competition, particularly with lynx, which is also lacking natural prey in the area. Our preliminary results contribute to wolf ecology and conservation in the Anatolian-Caucasian range, where further studies are urgently needed to generate baseline data.

Keywords: generalist carnivore; human-wildlife conflict; livestock scavenging; scats analysis.

***Corresponding author: Claudia Capitani,** Environment Department, University of York, Heslington, York, YO10 5DD, UK,
e-mail: claudia.capitani@york.ac.uk.
http://orcid.org/0000-0002-1899-8679
Mark Chynoweth: Department of Biology, University of Utah, 257 South 1400 East, Salt Lake City, 84112 UT, USA
Josip Kusak: Department of Biology, University of Zagreb, Heinzelova 55, 10000 Zagreb, Croatia
Emrah Çoban: KuzeyDoğa Society, Ortakapi Mah. Sehit Yusuf Cad. No:93 Kat:1, Merkez, Kars 36100, Turkey
Çağan H. Şekercioğlu: Department of Biology, University of Utah, 257 South 1400 East, Salt Lake City, 84112 UT, USA; KuzeyDoğa Society, Ortakapi Mah. Sehit Yusuf Cad. No:93 Kat:1, Merkez, Kars 36100, Turkey; and College of Sciences, Koç University, Rumelifeneri, Sariyer 34450, Istanbul, Turkey

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Wolves (*Canis lupus* Linnaeus, 1758) have been studied throughout their distribution, but very little is known about the Anatolian-Caucasian populations. Given its ecological and geographical continuity with vast areas of Central Asia and the Middle East, Turkey plays a central role in maintaining wolf populations throughout the region. The mountains of Turkey have served as a reservoir for the wolves surviving in Syria (Boitani 2003); yet, habitat loss, illegal killing, taking pups from the wild and vehicle collisions have resulted in a decline of wolves and other large-carnivore populations in Turkey (Şekercioğlu et al. 2011). Wolves are a species under protection from hunting according to the Article 4 of Turkey's Terrestrial Hunting Law (Tuğ 2005), and the Ministry of Forestry and Water Affairs is in charge for the management of this species (Anonymous 2012). Monitoring the status of the wolf population in Turkey is essential for the conservation of the species both in the country and over a broader area.

The local environmental organisation KuzeyDoğa Society (www.kuzeydoga.org), in collaboration with the General Directorate of Nature Conservation and National Parks, supported the creation of the first wildlife corridor in Turkey, eventually designated in 2011 with the Ministry of Forestry and Water Affairs (Şekercioğlu 2012). The corridor aims to connect isolated forest remnants through reforestation, to provide habitat connectivity and to facilitate the movements of large carnivores and their prey species. It will cover 22,346 ha and will extend for 136 km, from Kars province, north-eastern Turkey, to the extensive Caucasus forests on the Turkey-Georgia border. For the corridor to be effective, it is critical to improve the understanding of large-carnivore population dynamics and spatial ecology in the area.

Opportunistic surveys over the last decade suggested that primary prey species for wolf in Turkey are red deer (*Cervus elaphus* Linnaeus, 1758), roe deer (*Capreolus capreolus* Linnaeus, 1758), wild boar (*Sus scrofa* Linnaeus, 1758), brown hare (*Lepus europaeus* Pallas, 1778) and livestock (Can O.E. personal communication, Anonymous 2012). However, quantitative investigations on wolf diet and in particular on the relative share of wild and domestic ungulates have not been conducted to date.

In this study, we present the results of a quantitative assessment of wolf diet based on scat analysis conducted around Sarikamiş, Kars (Figure 1). Our goals are to contribute baseline data on large-carnivore ecology in the extended wildlife corridor area and to improve the general knowledge on wolf ecology in Turkey. The study area (approximately 550 km^2) is located on a high plateau at the intersection of Caucasus and Irano-Anatolian global biodiversity hotspots. Altitude ranges between 1900 and 3120 m asl. The landscape is characterised by patches of forest spaced out by grassland. Although fragmented, forests cover approximately 60% of the study area. Only 15% (49.7 km^2) of the forested areas is included in the Sarikamiş-Allahuekber Mountains National Park (hereafter SAM NP) (Figure 1).

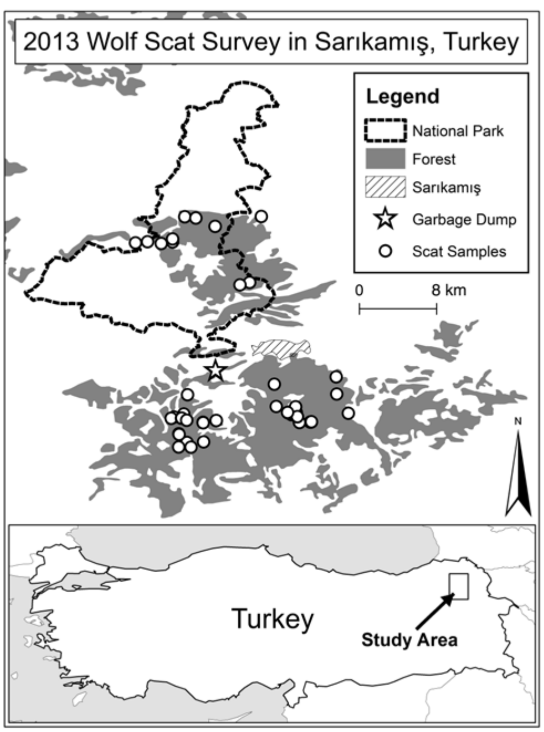

Figure 1: Location of the study area: SAM NP and surrounding forest in north-eastern Turkey. The SAM NP is fragmented forest in a landscape dominated by human activity, mainly livestock grazing. We collected 72 wolf scats during a 1.5-month period in May–June 2013.

Forests consist almost exclusively of Scots pine (*Pinus sylvestris* Linnaeus, 1753), while understory vegetation is scarce, with consequent scarcity of food resources for browsers.

Based on extensive camera trap surveys, wild boar is present at low density, and roe deer is rare (Chynoweth et al. unpublished data). On the contrary, livestock is abundant. About 851,445 livestock heads have been registered in the Kars province in 2012 (Ministry of Food, Agriculture and Livestock, Republic of Turkey). Cattle (*Bos taurus* Linnaeus, 1758), sheep (*Ovis aries* Linnaeus, 1758) and goats (*Capra hircus* Linnaeus, 1758) roam freely on pastures from April to November in average climate conditions. Wolf, bear (*Ursus arctos* Linnaeus, 1758) and lynx (*Lynx lynx* Linnaeus, 1758) are present in the area. At the time of this study, at least two wolf packs occupied the area, and reproduction was observed in one of them (Chynoweth et al. unpublished data). The scarcity of natural prey species leads wolves, as well as brown bears, to feed at garbage dumps and on livestock, increasing the human-carnivore conflict.

During 3 weeks between May and June 2013, we intensively searched for signs of wolf presence and collected scats over a 307 km network of forest roads (Figure 1). We identified wolf scats on the basis of their size, shape, content and smell (Jedrzejewski and Sidorovich 2010). Scats of uncertain origin were discarded. Despite drawbacks pointed out for scat analysis and the related prey use indices (Klare et al. 2011), this methodology is helpful in preliminary surveys of carnivores' diet and is still widely used, which facilitates comparisons with results from different studies.

Given the limited sample size, we tested for adequacy of sample effort by calculating the Brillouin diversity index (Hass 2009), according to the equation $Hb=\frac{\ln N!-\sum \ln n_i}{N}$ where Hb is the diversity of prey in the sample, N is the total number of individual prey categories in all samples and n_i is the number of individual prey in the ith category (Brillouin 1956). An Hb diversity curve was calculated by bootstrapping the sample 10,000 times with replacement to obtain a mean Hb and 95% confidence interval, varying the sample size from 2 to 100, in increments of 2. The Hb increment curve was then calculated from the incremental change in each mean Hb with the addition of two more samples. Adequacy of sample size was determined by whether asymptotes were reached in both curves when plotted against the sample size.

For every sample, the macroscopic components (hairs, bones, hooves, claws, garbage remains, etc.) were separated from the remaining matrix, and the volume of each item was visually estimated to the nearest 5%. In most cases, mammal hairs were identified by examination of the medulla and cuticular surface structures under a microscope and compared with a specific hair atlas (Debrot et al. 1982). In few cases, hair and bones were compared with reference collections and museum specimens. For some samples, the species could not be determined, because of the poor quality of the remains or the lack of specific reference material.

The utilisation rate of different food items was calculated by frequency of occurrence per item (hereafter FO) and mean percent volume (hereafter MPV), following previous studies (Ciucci et al. 1996, Capitani et al. 2004). Remains contributing <5% of the total scat volume were considered as traces and not accounted for utilisation rate. Utilisation indices, in particular FO, tend to underestimate the share of big prey compared to the small ones and can be misleading when prey greatly differ in size (Klare et al. 2011). Therefore, we applied a biomass model to convert the equivalent number of scats in biomass and calculated the relative share of prey categories. Biomass models are sensitive to the weights of prey used during experimental feeding trials (Klare et al. 2011); thus, we chose the model which would cover the range of prey weights found in our sample (Table 1). We used the equation developed by Floyd et al. (1978), Y=0.02X+0.038, where Y is the kilograms of prey per collectable scat and X is the mean prey weight (kg). We excluded garbage remains and undetermined mammals that we could not estimate a mean weight. We calculated the biomass using the prey weights reported in other studies (Rigg and Gorman 2004, Tumanov 1998, Van Duyne et al. 2009, Mattioli et al. 2011; Table 1).

Table 1: Composition of wolf diet in SAM NP and surrounding forest in north-eastern Turkey, based on scats analysis (n=72; May–June 2013).

Food category	MPV (%)	FO (%)	BM	PW (kg)
Squirrel	19.4	17.5	4.6	0.5[a]
Cattle	19.1	17.5	61.8	250[b]
Hare	12.8	13.8	3.7	5
Small rodents	12.8	12.5	3.0	0.2
Sheep	10.4	11.3	7.4	40[c]
Undetermined livestock	8.7	10.0	6.2	40[c]
Wild boar	8.0	7.5	5.0	33.7[a]
Undetermined mammal	4.2	5.0	–	–
Horse	2.8	2.5	8.0	220[c]
Bear	1.4	1.3	0.5	13[d]
Garbage	0.3	1.3	–	–
Total	100	100	100	

Prey abundance is quantified by MPV, FO and biomass share (BM) according to Floyd et al. 1978. [a]Mean weight of wild boar was estimated accounting for the weight classes identified in the scats, following Mattioli et al. (2011). Mean weights of prey (PW) followed previous studies: [b]Rigg and Gorman (2004), [c]Van Duyne et al. (2009) and [d]Tumanov (1998).

Finally, we investigated the relationship between diet composition and livestock availability on pastures. In 2013, livestock was reported to begin grazing on pastures from the third week of April. We estimated the deposition time of our samples by collection date and degree of degradation). Samples with an estimated deposition time up to the third week of April were assigned to the season when livestock is not available to predators (hereafter season A). Remaining samples were assigned to the season when livestock are grazing on pastures and are vulnerable to predation (hereafter season B). We compared the use of two prey groups – specifically livestock and small mammals – and grouped the main food categories to maintain adequate sample size and to account for the undetermined categories within each group. We tested for seasonal differences in the mean volume of each group by applying the Wilcoxon rank-sum test.

Statistics were performed in R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

During the surveys, we collected 72 wolf scats useful for diet analysis, whose deposition time we estimated to vary from mid-March to mid-June. Fresh scats (deposition time <2 days) were not collected for the diet analysis since they were intended for other purposes. Both Hb index mean and incremental change curves reached an asymptote, and the incremental change declined below 1% at ≥36 samples (Figure 2), indicating that the sampling effort was adequate.

Given information collected through camera trapping (Chynoweth et al. unpublished data), we assumed that

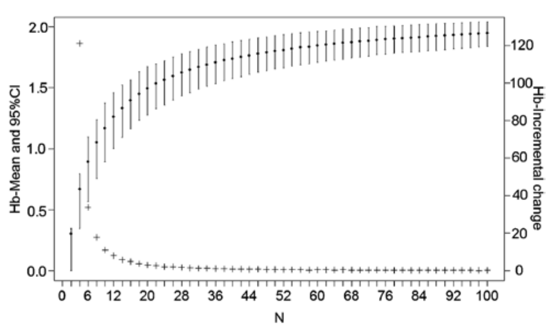

Figure 2: The Brillouin diversity index (Hb) mean and 95% confidence intervals (CI) and incremental change curves. Mean and 95% CI were obtained by resampling with replacement 10,000 times. Mean and incremental change curves reached an asymptote, and the incremental change declined below 1% at ≥36 samples.

prey availability varies little across the study area and analysed the data cumulatively. Analysis of 72 scats documented a total of 80 food items, which were assigned to 11 food categories (Table 1). Only eight scats contained two different food items at the same time, and so MPV and FO resulted highly correlated (Spearman' correlation index, R_s=0.98, p<0.01).

The most frequent food categories were squirrel (*Sciurus vulgaris* Linnaeus, 1758 and *Sciurus anomalus* Gmelin, 1778) and cattle, followed by hare, sheep and small rodents (Table 1), which included black rat (*Rattus rattus* Linnaeus, 1758) and other undetermined rodent species. Overall, small mammals were the most abundant in scats, summing up to 45.2% of MPV. Livestock comprised 40.9% of MPV, including horse and other undetermined livestock remains, which most likely belong to either sheep or goat. Wild boar remains were found in six samples only, including one piglet. Though wolves have been frequently observed feeding at the main dump site of the village (authors' observations), garbage remains were rare; food remains taken at the dump could be difficult to recognise unless associated with undigested material. Finally, very exceptionally, one scat contained hairs and a claw from a bear cub.

As expected, biomass shares largely differed from utilisation indices (Table 1). Livestock represented 83.7% of biomass, while small mammals share totally amounted to 10.8% (Table 1). The use of livestock and small mammals differed between seasons A and B (Figure 3). Livestock increased from 27.8% of MPV in season A to 54.1% of MPV in season B (Wilcoxon test, W=477.5, p=0.031). On the contrary, small mammals decreased from 58.3% to 31.9% of MPV (Wilcoxon test, W=826.5, p=0.025).

According to our results, Sarikamiş wolves have a clear opportunistic feeding behaviour, using a wide variety of food items but mostly relying on anthropogenic resources, as found in other areas where wild prey are scarce (see Meriggi and Lovari 1996, Peterson and Ciucci 2003 for a review). Furthermore, our data suggest a seasonal variation in wolf diet due to the presence of free-ranging livestock on pastures, a behaviour that has been observed in other agricultural landscapes (Morehouse and Boyce 2011). The scarce use of wild ungulates confirms that the density of these species is very low in the study area. This scarcity of natural prey and the opportunistic feeding behaviour of wolves are probably leading to trophic niche overlap with other carnivores, particularly with lynx, which is also lacking natural prey in the area (i.e., roe deer) and whose diet can be influenced by wolf presence (Lelieveld 2013).

Our observations suggest that the wolves' feeding behaviour in Sarikamiş is related to local husbandry practices. Open-air disposal of livestock carcasses to some extent supports wolves that can scavenge on carcasses when live prey is not available (Blanco and Cortés 2007). These carcasses may also attract wolves to areas near livestock and could encourage livestock depredation (Morehouse and Boyce 2011, Tourani et al. 2014). The authors observed numerous openly disposed carcasses around Sarikamiş area and once in broad daylight wolves could be observed scavenging on a cattle carcass abandoned on the roadside a few kilometres from Sarikamiş village. Since conflicts are likely to be unevenly distributed across the landscape, assessing local conditions of farms and livestock husbandry practices is needed to provide specific mitigation tools (Rigg et al. 2011).

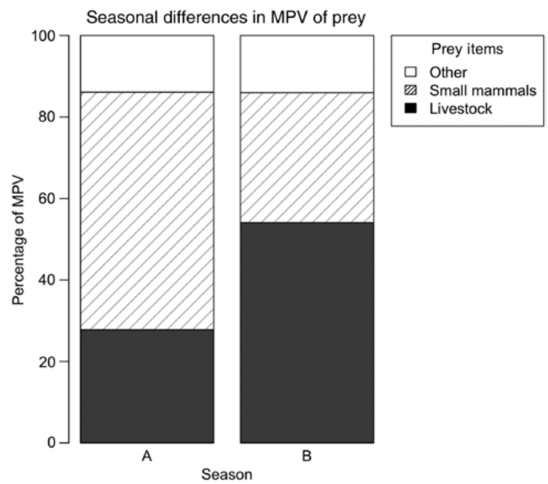

Figure 3: MPV of prey found in 72 scats collected from SAM NP and surrounding forest in north-eastern Turkey in season A (mid-March to third week of April) and season B (fourth week of April to mid-June). Livestock increased from 27.8% in season A to 54.1% in season B (Wilcoxon test, W=477.5, p=0.031). Small mammals decreased from 58.3% to 31.9% (Wilcoxon test, W=826.5, p=0.025).

Synanthropy represents a major threat for wolves in Sarikamiş because wolves are more likely to approach human settlements to access trophic resources. This enhances wolf-human encounters probability and results in increased risks of direct persecution, vehicle collisions (Fritts et al. 2003) and hybridisation with dogs (Kopaliani et al. 2014). Human-induced mortality cases were often reported in the study area (Chynoweth et al. unpublished data), though detailed data on the wolf-livestock-human dynamics are currently lacking.

As proposed for other areas where wolves largely depend on anthropogenic resources, appropriate management of garbage dumps and of livestock carcass disposal sites could reduce wolf-livestock conflicts and minimise the chances of human-wildlife conflict and consequent wolf mortality (Hosseini-Zavarei et al. 2013, Tourani et al. 2014). Such interventions should be realised in conjunction with actions for improving habitat suitability, for example, the current efforts of the KuzeyDoğa Society to improve habitat by increasing protected area coverage in the region and to reforest the newly designated wildlife corridor. Future efforts should also include management of wild ungulate populations to increase the density of wild prey, which could reduce livestock depredation to a certain extent (Meriggi et al. 2011). As a potential solution to mitigate human-wildlife conflict, wildlife managers should consider reintroduction of native wild ungulates (Meriggi and Lovari 1996), such as red deer that has been reintroduced to other parts of Turkey (Gümüşhane Haberi 2013) and the Caucasus (World Wildlife Fund 2014).

Changes in socio-economic conditions could lead to an alteration of wolf-prey dynamics in the study area, where the number of livestock heads has dropped sharply in the last decade (-78.5% goats, -15.6% cattle in Kars province, source Republic of Turkey Ministry of Food, Agriculture and Livestock). In the overall region, cattle stock dropped from about 15 million to 900,000 heads in Kars, Igdir and Ardahan provinces in the past 50 years (Nuri Vatan, personal communication). Looking at future scenarios, continued abandonment of livestock husbandry could exacerbate wolf-human conflict and, potentially, cause a decline of the wolf population due to persecution and lack of prey. On the contrary, proper management strategies could support an alternative scenario, where abandonment of mountain areas by humans and decreased grazing pressure by livestock would lead to the increase of forest cover, wild ungulates and ultimately biodiversity (Falcucci et al. 2007, Chapron et al. 2014).

The results of this study represent preliminary efforts to investigate wolf ecology in the study area, though we recognise that the low number of samples and the short collection period could have biased our results. Further investigations of year-round predator-prey dynamics, local husbandry practices and interspecific interactions are currently taking place. Long-term survey of wolf ecology in the study area is required to design locally tailored solutions to human-wildlife conflict, and, more generally, it can contribute to the escalating debate on large-carnivore conservation in human-dominated landscapes (Chapron et al. 2014).

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APPENDIX C

ANTHROPOGENIC FOOD RESOURCES FOSTER THE COEXISTENCE OF DISTINCT LIFE HISTORY STRATEGIES: YEAR-ROUND SEDENTARYAND MIGRATORY BROWN BEARS

Cozzi, G., M. Chynoweth, J. Kusak, E. Çoban, A. Çoban, A. Ozgul, and Ç. H. Şekercioğlu. 2016. Anthropogenic food resources foster the coexistence of distinct life history strategies: year-round sedentary and migratory brown bears. Journal of Zoology 300(2): 142-150. Reprinted with permission from John Wiley & Sons, Inc.

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Anthropogenic food resources foster the coexistence of distinct life history strategies: year-round sedentary and migratory brown bears

G. Cozzi[1], M. Chynoweth[2], J. Kusak[3], E. Çoban[4], A. Çoban[4,5], A. Ozgul[1,*] & Ç. H. Şekercioğlu[2,4,6,*]

1 Population Ecology Research Group, Department of Evolutionary Biology and Environmental Studies, Zurich University, Zürich, Switzerland
2 Department of Biology, University of Utah, Salt Lake City, UT, USA
3 Biology Department, Veterinary Faculty, University of Zagreb, Zagreb, Croatia
4 KuzeyDoğa Society, Kars, Turkey
5 Department of Parasitology, Institute of Health Sciences, Kafkas University, Kars, Turkey
6 College of Sciences, Koç University, Istanbul, Turkey

Keywords
anthropogenic food resource; behavioral plasticity; behavioral type; habitat selection; migration; movement patterns; *Ursus arctos*.

Correspondence
Gabriele Cozzi, Population Ecology Research Group, Department of Evolutionary Biology and Environmental Studies, Zurich University, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland.
Email: gabriele.cozzi@uzh.ch

*Co-senior author.

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Abstract

Plastic behavioral adaptation to human activities can result in the enhancement and establishment of distinct behavioral types within a population. Such inter-individual behavioral variations, if unaccounted for, can lead to biases in our understanding of species' feeding habits, movement pattern and habitat selection. We tracked the movements of 16 adult brown bears in a small and isolated population in northeast Turkey to (1) identify inter-individual behavioral variations associated with the use of a garbage dump and (2) to examine how these variations influenced ranging patterns, movements behavior and habitat selection. We identified two remarkably distinct behavioral types: bears that regularly visited the dump and remained sedentary year-round and bears that never visited the dump and migrated 165.7 ± 20.1 km (round-trip mean cumulative distance $\pm$ SE) prior to hibernation to search for food. We demonstrated that during migratory trips, bears moved more rapidly and were less selective in habitat choice than during the sedentary phase; during the migration phase, forest cover was the only important environmental characteristic. Our results thus reinforce the growing evidence that animals' use of the landscape largely changes according to movement phase. Our study shows that anthropogenic food resources can influence food habits, which can have cascading effects on movement patterns and hence habitat selection, ultimately resulting in the establishment of distinct behavioral types within a population. Identification and consideration of these behavioral types is thus fundamental for the correct implementation of evidence-based conservation strategies at the population level.

Introduction

As a result of increasing human pressure, many wildlife species live in modified and fragmented landscapes (Hanski, 1999; Goudie, 2013). To cope with novel and constantly changing environments, cognitively complex species may develop plastic strategies (Valeix *et al.*, 2012; Sol, Lapiedra & González-Lagos, 2013; Flack *et al.*, 2016), which can result in the establishment of distinct alternative behaviors (hereafter behavioral types) within a population (Gill, Norris & Sutherland, 2001; Elfström *et al.*, 2014). Such inter-individual variation in behavioral types, if unaccounted for, can lead to biases in our understanding of species' life history traits, movement pattern and habitat selection (Elliot *et al.*, 2014; Weimerskirch *et al.*, 2015). Therefore, careful identification and consideration of observed variation in behavioral types is fundamental for the correct implementation of evidence-based conservation strategies at the population level.

Animal behavior, life history, movement patterns and habitat selection can be influenced by environmental variations (Nelson, 1998; Stien *et al.*, 2010), by changes during different stages of the life cycle, such as the transition from a sedentary to a dispersing movement mode (Elliot *et al.*, 2014), and by anthropogenic activities (Ordiz *et al.*, 2013; Flack *et al.*, 2016). For example, the access to additional food sources resulted in a subpopulation of otherwise migrant white storks *Ciconia ciconia* to remain resident year-round (Massemin-Challet *et al.*, 2006). Similarly, spatiotemporal variation in anthropogenic food resources influenced black-tailed gull *Larus crassirostris* foraging trips and selection of feeding grounds during the incubation and hatching period (Yoda *et al.*, 2012). Changes in feeding habits, movement patterns and habitat selection thus provide us with a dynamic insight into an animal's sensitivity and adaptation to anthropogenic activities and alteration of the landscape. Information on movement patterns and habitat selection during long-distance movements can help us further understand a species' requirements during different stages and under changing environmental conditions. This knowledge is necessary to model movement of individuals among habitat fragments, implement evidence-based plans to create wildlife corridors and promote connectivity among populations (Palmer, Coulon & Travis, 2014; Runge *et al.*, 2014).

A species that shows remarkable adaptation to human-altered landscapes is the brown bear *Ursus arctos*. Bears are well known to complement their diet at garbage dumps, campsites and residential areas. The frequent use of these human-related food resources often leads to individual bears becoming 'problem' animals, which are frequently relocated or killed by management agencies (Peirce & Van Daele, 2006). The access to artificial food resources has been reported to reduce bear home-range size (Blanchard & Knight, 1991), despite home range in wild bears is typically not directly influenced by food availability (Dahle & Swenson, 2003). Human activity and disturbance further influence the spatiotemporal use of resources and movement patterns (Martin *et al.*, 2010; Ordiz *et al.*, 2013). Brown bears' behavioral plasticity and individual opportunistic behavior may thus result in the establishment of alternative life history traits, such as alternative feeding strategies, movement patterns and habitat selection among individuals with access to artificial food resources.

The aim of this study was to investigate the effects of an anthropogenic food resource, a city garbage dump, on feeding and ranging patterns of a small and isolated subpopulation of bears in north-eastern Turkey. In particular, we examined whether all bears used the dump to the same extent or whether they exhibited distinct feeding strategies. We expected that, if distinct feeding strategies were established within the population, they should be reflected in distinct spatial and movement patterns. We therefore tested for differences in movement patterns and movement parameters, and investigated habitat selection between quantitatively distinct sections of the entire path (i.e. the chronological collection of all its GPS locations) of each individual. The obtained information was crucial for the implementation of local management interventions, as there were governmental plans for closing the dump, with predicted imminent changes in the bears' foraging strategies. Our results on habitat selection have also imminent conservation implications, as they will be used to optimize the design of the first wildlife corridor in Turkey (Şekercioğlu 2012), whose globally important biodiversity and wildlife populations are experiencing a major conservation crisis (Şekercioğlu *et al.*, 2011).

Materials and methods

Study area

The core study area (~550 km^2) was located in north-east Turkey and included the Sarıkamış Forest Allahuekber Mountains National Park (hereafter SAMNP) and the surrounding landscape (Fig. 1). The climate is continental, with temperate summer months during June–September (average monthly: 13 to 18°C), and cold winter months with snowfalls during November–March (average monthly: −10 to 0°C).

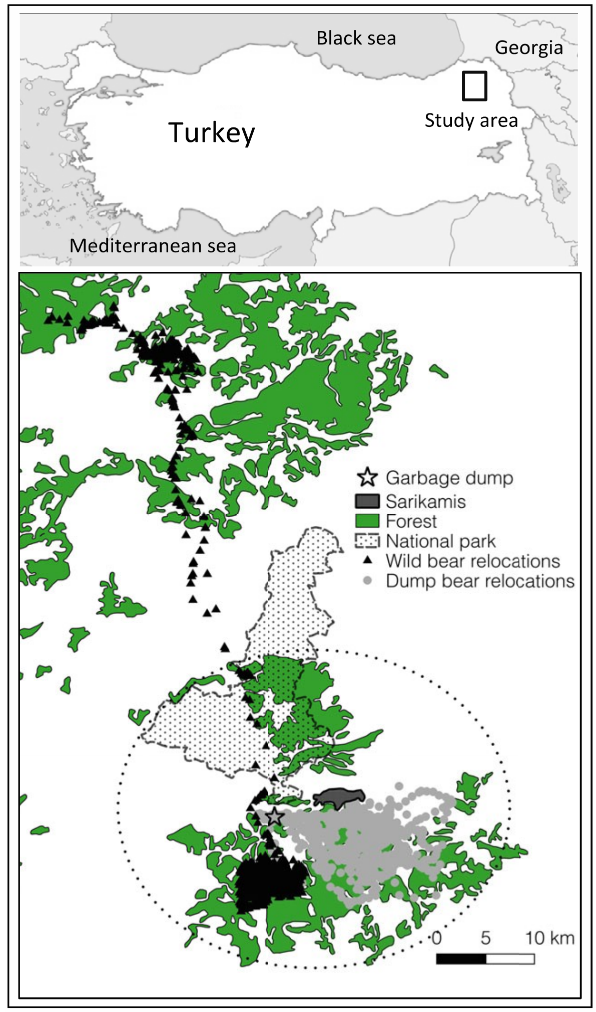

Figure 1 The study area in north-eastern Turkey. The dotted ellipse represents the core study area including Sarikamiş forest and surrounding pastures. The extended study area enclosed all locations visited by the bears during migratory trips outside the core study area. GPS relocations of one migrating bear (wild bear) and one bear resident year-round (dump bear) are shown as an example.

SAMNP covers an area of 225.2 km^2, but only 49.69 km^2 is forested (Capitani *et al.*, 2016). The remaining 278.7 km^2 of forest is not protected, for a total forest cover of 328.4 km^2 (hereafter Sarıkamış forest). Sarıkamış forest is almost exclusively composed of Scots pine *Pinus sylvestris*. Open pastures and arable land surround patches of forest (Fig. 1). Sarıkamış forest is fragmented, and is heavily used for logging, grazing, harvesting and recreation. The understory vegetation is over-exploited, with consequent food scarcity for grazers (Capitani *et al.*, 2016) and frugivorous species. Wild ungulate prey species are very rare (Capitani *et al.*, 2016). Wolves *Canis lupus* and Caucasian lynx *Lynx lynx dinniki* also inhabit the study area (Chynoweth, Coban & Şekercioğlu, 2015; Capitani *et al.*, 2016). Although a viable bear population is known to occur ca. 100 km away in the Black Sea forests (Can & Togan, 2004), no information was available on the bear population in the SAMNP region prior to this study.

Additional fragmented patches of forest are scattered throughout the landscape considerably far (>12 km) from Sarıkamış forest (Fig. 1). Together with their surrounding landscape, these forest remnants formed the extended study area of approximately 5000 km^2. This extended area enclosed all locations visited by the bears during long-distance movements outside the core study area (see below).

In the middle of the core study area is the city of Sarıkamış (E 42.595°, N 40.332°) with a population of 18 000 inhabitants (Fig. 1). An unfenced garbage dump lies about 3 km west of the outskirts of Sarıkamış and represents a year-round additional source of food (Fig. 1). Bears visit the dump at night and feed on food scraps (pers. observ.). The proportion of the bear population visiting the dump and its effects on foraging behavior, movements and demographic traits were not previously investigated.

Fieldwork and collection of GPS movement data

We captured and collared 10 adult males and six adult females from a small and isolated population in north-eastern Turkey between September 2012 and June 2014. Immobilized bears were fitted with GPS/GSM or GPS/Iridium radio-collars (GPS Plus; Vectronic Aerospace GmbH, Berlin, Germany) programmed to record one GPS location every hour. Bears were monitored for a mean duration of 296 days (range: 125–590 days). GPS acquisition rate was >90% for 15 out of 16 individuals; one collar consistently performed poorly (acquisition rate ≈ 50%) (Appendix S1). To avoid including inaccurate GPS locations in the dataset, we removed all locations with a position dilution of precision > 10 (Elliot *et al.*, 2014). During the winter, when bears hibernate in caves or holes (interquartile range: from November 23rd–December 3rd to March 6th–April 1st), the GPS typically failed to acquire satellites; therefore, in the analyses, we only used each individual's location data collected pre- and post-individual hibernation date.

Identification of inter-individual variation in the use of the garbage dump

For each bear and for each year, we summed the number of GPS locations at the garbage dump each month. We used a generalized additive mixed model framework to investigate the relationship between month and the number of locations at the dump, while allowing for potential nonlinear relationships (Wood, 2006). We entered individual gender (Appendix S1) as categorical covariate, whereas we treated individual identity as random intercept. This approach allowed us to identify two distinct categories. In subsequent analyses, we therefore investigated and compared movement modes, movement pattern and habitat selection between these two categories.

Investigation of movement modes and sub-division in discrete movement phases

To investigate whether the two different categories exhibited different movement modes, we fitted four competing *a priori*-defined functions representing alternative movement modes to the entire path of each collared bear. The four movement modes were as follows: (1) year-round residency, (2) dispersal, (3) migration and (4) nomadism (*sensu* Börger & Fryxell, 2012; Fig. 2). This analytical method relies on the net squared displacement (NSD) statistics combined with a nonlinear hierarchical modeling framework (Börger & Fryxell, 2012). Appendix S2 provides a detailed mathematical and visual representation. We developed an additional metric to ensure that the NSD did not assign long-distance movement modes such as migration to small-scale movement patterns occurring at the local scale. For each individual, we calculated the ratio between the maximum and the median of the observed net displacement (ρ). In this metric, the maximum net displacement for migrating individuals should increase faster than the median, thus increasing the value of ρ. Empirical evidence suggested that $\rho > 5$ corresponded to actual migration events; while ρ between 1.5 and 2.5 were typical of individuals moving at the local scale (Fig. 2, Appendix S1).

In a second step, we visually sub-divided the movement mode of each individual in discrete movement phases: (1) sedentary, (2) roaming and (3) stopover (Fig. 2). For example, an individual characterized by year-round residency was assigned a sedentary phase for its entire path (Fig. 2). On the other hand, the entire path of a migrating individual was chronologically divided into sedentary, roaming, stopover (the final site of the migratory trip), roaming and sedentary phases (Fig. 2). Here, migration refers to a particular movement mode and hence to an entire movement trajectory, and not to the actual displacement phase between two distinct geographic areas, which we define as the roaming phase. We then investigated differences in movement parameters and habitat selection between the three different movement phases between and within the two distinct bear categories (see Calculation of movement parameters and Step selection function).

Calculation of movement parameters

We first investigated differences in movement parameters (i.e. step length and turning angles) between day and night, as bears in European human-dominated landscapes are known to be predominantly nocturnal (Kaczensky *et al.*, 2006). Only consecutive locations 1 h apart were considered. Due to the considerable differences detected between the dial periods, we recalculated movement parameters for the sedentary, stopover and roaming phases using night-only data.

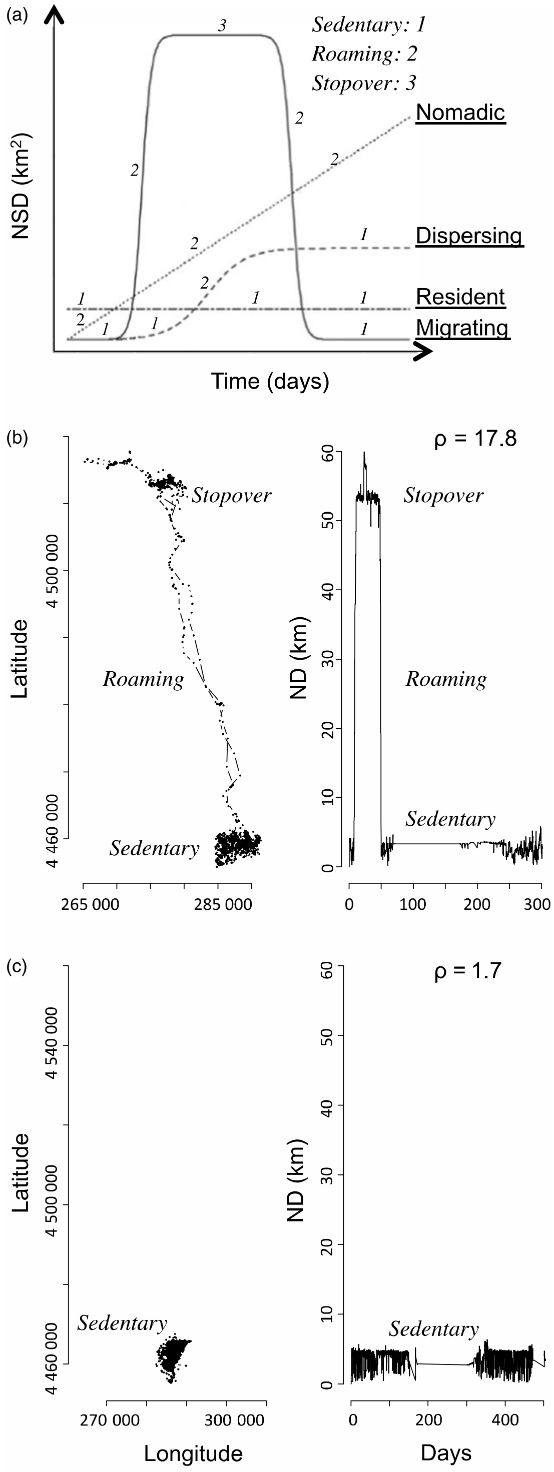

Figure 2 Characterization of movement trajectories by means of the net squared displacement approach. (a) Graphical representation of four alternative movement modes (underlined) and sub-division in three discrete movement phases (italic) (modified from Bunnefeld *et al.* 2011). For instance, a migratory movement mode is characterized by two sedentary phases, two roaming phases and one (or more) stopover phase. A resident mode is characterized by a sedentary phase throughout the entire movement path. (b) Observed trajectory corresponding to a migratory movement mode (left panel) and its corresponding ND (right). Discrete movement phases are shown. Each dot in the left panel represent a GPS location collected at hourly intervals; lines connect consecutive locations. In the right panel, horizontal net displacement sections represent the hibernation period (c) Observed trajectory corresponding to a resident movement mode (left) and its corresponding ND (right). ρ are given for both movement modes: a low value indicates small-scale movements (see main text for further details).

In a subsequent step, we investigated differences in step length between the two bear categories and across the three movement phases using a mixed-effects model. We included sex and season as additional categorical covariates, and individual as a random intercept. The inclusion of season as covariate to control for seasonal effects was due to the fact that the roaming and stopover phases were highly seasonal, and thus differences in step lengths between these two phases and the sedentary phase could have arisen through seasonal differences instead of through genuine differences among movement phases.

Step selection function

We used a step selection function (SSF) framework (Fortin *et al.*, 2005) to infer the effects of landscape structures on bear movements during the sedentary, stopover and roaming phases. For each phase, we pooled the data irrespective of bear category. SSFs typically assume an exponential function of the form:

$$w(X) = \exp(\beta_1 x_1 + \beta_2 x_2 \ldots \beta_n x_n)$$

where β_i are the coefficients estimated by conditional logistic regression associated with landscape variables x_i. Steps with higher SSF scores $w(\boldsymbol{X})$ are more likely to be chosen by the animals (Fortin *et al.*, 2005), and $\beta = 0$ indicates absence of selection (Forester, Im & Rathouz, 2009). For each observed step, we created a set of 10 alternative steps; the end of these steps represented alternative locations that the animal could have chosen. A step is here defined as the vector between two consecutive locations. Step length refers to the Euclidean distance between consecutive locations. Following Fortin *et al.* (2005), these alternative steps were created by drawing step length and turning angles from movement phase-specific empirical distributions built with the data collected from the other monitored individuals (see Appendix S3, for more details).

Landscape characteristics at the observed locations were regressed against those at the alternative locations. Landscape characteristics included distance to the nearest village, distance to the nearest paved road, altitude, slope, aspect and forest cover (Appendix S3). Because selection partially depends on the scale at which a resource is distributed in the landscape, a linear variable 'distance to the previous location' was included in the model to increase the robustness of our analysis (Forester *et al.*, 2009). We implemented a two-stage approach using the TwoStepClogit package (Craiu *et al.*, 2011) in R (The R Foundation for Statistical Computing; version 3.0.3) to allow for differential habitat selection responses among individuals (Fieberg *et al.*, 2010). We removed GPS locations at the garbage dump from the analysis of the effect of landscape structure on the bears' habitat selection. This was because the dump is not a feature characteristic of the entire landscape, and including these locations would have resulted in an over-representation (i.e. inflated selection) of the environmental variables (such as forest cover) at the dump. We followed the 10-fold cross-validation procedure suggested by Boyce *et al.* (2002) to examine model performance (see Appendix S3, for more details).

Results

Inter-individual variation in the use of the garbage dump

We observed two categories of individuals: bears that visited the dump (hereafter dump bears) and bears that never did (hereafter wild bears). Dump bears included three females and seven males; wild bears included three females and three males. Visits at the dump significantly varied across months ($F_{edf\ =\ 5.1} = 8.93$, $p < 0.001$) but not between gender ($t = 1.5$, $P = 0.13$). Visits increased toward the second half of the year (>40% increase between March and September) and peaked in late August (Fig. 3). Dump bears hibernated on average 3 days after wild bears (November 25th and November 22nd respectively), suggesting that this life history trait is not influenced by the use of the dump. We captured three dump bears in the forest 5.7, 7.2 and 10.1 km from the dump, and we observed three wild bears in the vicinity of, but never at, the dump (closest recorded location 0.5, 1.3, 2.0 km). We therefore concluded that capture site locations did not explain the existence of the two observed categories.

Movement modes

All wild bears migrated outside Sarikamiş forest. Five individuals made long-distance migratory trips characterized by a maximum linear displacement from the site of capture of 36–108 km, and lasted between 23 and 72 days. One male made a shorter migratory trip with a maximum linear displacement of 17 km, which lasted only 7 days (Appendix S5). Overall, the mean cumulative migratory round-trip distance was 165.7 ± 20.1 km. Migratory trips occurred closely prior to hibernation between the mean dates September 18th (range: August 29th–September 30th) and November 1st (range: October 10th–December 11th; Fig. 3). The only exception was the male that did a shorter trip of 7 days in June. His collar stopped recording GPS locations on October 9th, we cannot

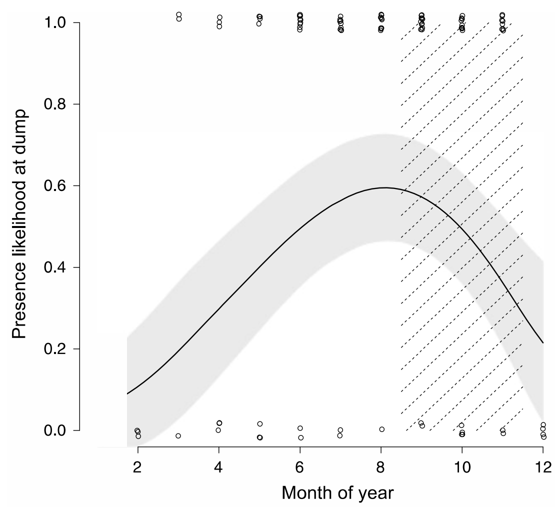

Figure 3 Presence likelihood at the city garbage dump across a year. Confidence intervals are shown in gray. Bears that visited the dump (dump bears) remained resident year-round. On the other side, bears that never visited the dump (wild bears) migrated before hibernation; the hatched area shows the migration period.

know whether this bear may have also migrated after that date. We conservatively classified one wild male as nomadic (Appendix S4). His collar stopped working on November 11th and we therefore do not know whether or not he had returned to Sarikamiş forest before hibernation.

Dump bears never migrated, with the exception of an old female that made a shorter migratory trip of 27 km that lasted 13 days (Appendix S5). Given the short duration of this trip, we cannot exclude that this was a prospecting trip rather than real migration. The same applies to the wild male that made a short trip of 7 days.

Movement parameters

The distribution of step lengths and turning angles varied considerably between daytime and nighttime (Fig. 4a,b). In particular, during the day, bears were characterized by turning angles close to 180° and short steps (mean ± SE = 263 ± 5 m), which are typical of stationary (i.e. resting) or small-scale searching (e.g. feeding) behavior. To the contrary, at night, their movement pattern was more directional with turning angles close to 0° and displacements occurred at a quicker pace (mean ± SE = 535 ± 5 m). At night, the distribution of step lengths and turning angles showed more consistent patterns across the three movement phases (Fig. 4c,d). Nevertheless, steps during the roaming phase appeared longer and more directional.

We did not detect differences in overall nighttime step lengths between wild and dump bears ($F_{1,12} = 0.4$, $P = 0.52$) nor between gender ($F_{1,12} = 1.48$, $P = 0.25$). Step length differed significantly among movement phases ($F_{2,34} = 511.8$,

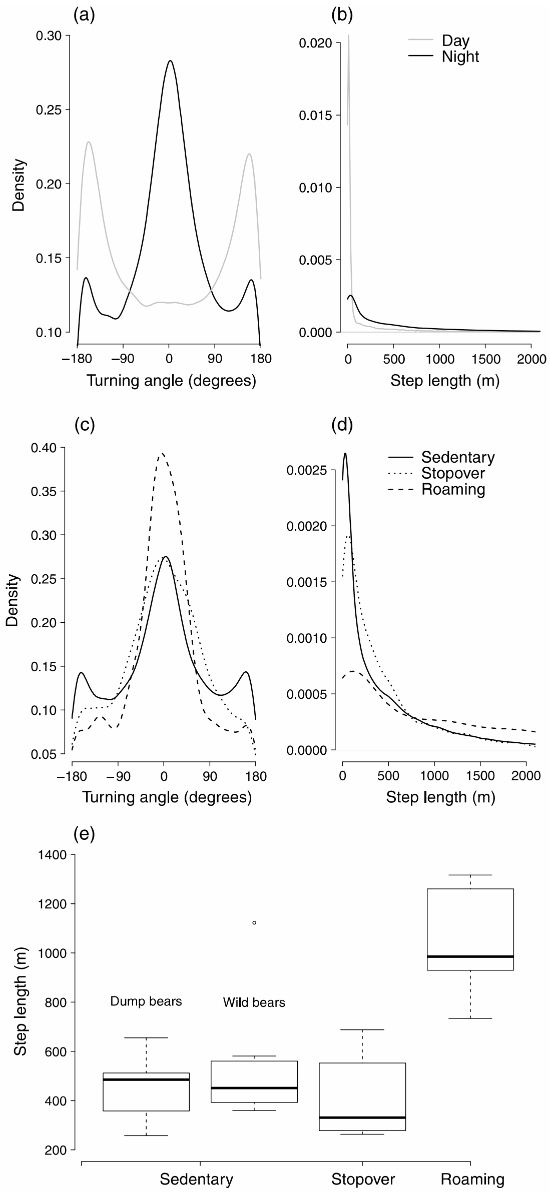

Figure 4 Changes in movement parameters (i.e. step length and turning angle) between day and night (a, b), and among different movement phases at night (c–e). In panels c and d, sedentary phase data of dump and wild bears are pooled. Panel e shows differences between dump and wild bears (the latter do not have a migratory and stopover phase).

$P < 0.001$). Irrespective of behavior and sex, steps during the roaming phase were twice as long (predicted mean step length 940 m) than steps during the sedentary (439 m) and stopover (420 m) phase (Fig. 4e). We detected a significant seasonal effect ($F_{2,34} = 62.7$, $P < 0.001$) with a tendency toward shorter steps late in the season, suggesting that the difference between the sedentary and roaming phases did not depend on seasonal factors, but rather on genuinely different patterns during the movement phases. If this was not the case, a reduction, rather than an increase, in step length during the roaming phase should have been observed.

Habitat selection

Results were based on the data from wild and dump bears for the sedentary phase and on data from wild bears for the roaming and stopover phase. At the population level, bears appeared to be less 'selective' in their habitat choice during the roaming phase than they were during the sedentary and stopover phase. During roaming, out of the six landscape variables, only the β coefficient for forest had a value >2 SE from 0 (Table 1). This indicates a significant association between forest and the bears' chosen paths. Nevertheless, we observed high inter-individual variation for forest selection (Table 1).

During the sedentary phase, forest, slope and distance to roads significantly influenced the animals' step selection (Table 1). The positive effect of slope and forest suggests that, at the population level, animals sought forested locations and steeper slopes. The negative relationship with distance to roads indicates that locations far away from roads were less likely to be chosen. During the stopover phase, bears preferred forest and locations far from villages (Table 1). Based on 10-fold cross-validation procedure, our models provided excellent fit for the sedentary phase ($r_s = 0.95$) and only moderate for the stopover ($r_s = 0.23$) and roaming ($r_s = 0.12$) phase.

Discussion

We defined two categories of bears based on high-resolution GPS data from 16 adult individuals: dump bears (i.e. bears that regularly visited a garbage dump) and wild bears (i.e. bears that never did). Substantial differences in movement patterns between dump and wild bears allowed us to identify two distinct behavioral types. While dump bears were characterized by year-round residency, wild bears undertook migratory round-trips >100 km. Our results thus showed that differences in life history traits within the study population were associated with the exploitation of a human-related food source. To the best of our knowledge, such behavioral dichotomy within a population of brown bears has never been reported; and only a few cases are known for black bears *Ursus americanus* (Noyce & Garshelis, 2011; Liley & Walker, 2015). Extreme variation in migratory behavior have been shown to have direct energetic and fitness consequences (Weimerskirch *et al.*, 2015; Flack *et al.*, 2016). Investigation of differences in key demographic parameters such as survival and reproductive rate between the two behavioral types is therefore required to better understand the population dynamics of the study system.

Migration is conceivably linked to a seasonal availability of resources, such as food and mates (Dingle, 2014). Because migratory trips occurred right before hibernation and because

Table 1 Population level coefficients, estimated standard errors and variance of random coefficients from a mixed conditional logistic regression of movement steps on six different environmental variables during the sedentary, stopover and roaming phases. For the sedentary phase, data from dump and wild bears were pooled

	Sedentary phase			Stopover phase			Roaming phase		
	β	SE	Var	β	SE	Var	β	SE	Var
Distance to previous	−0.000326	0.00019	5.5e-07	−0.000376	0.00038	8.5e-07	0.000047	0.00012	8.4e-08
Altitude	0.000828	0.00069	5.1e-06	−0.000176	0.00087	2.8e-06	0.001629	0.00136	1.1e-05
Slope	0.012802*	0.00273	5.1e-05	−0.002962	0.0028	2.1e-06	0.008096	0.00877	2.9e-04
Aspect	−0.000156	0.00014	4.7e-08	0.000536	0.00035	1.9e-07	−0.000019	0.0004	1.5e-07
Forest	0.262084*	0.09703	1.0e-01	0.393145*	0.16658	8.7e-02	0.368015*	0.13588	1.9e-02
Distance to village	0.000154	0.00013	2.2e-07	0.000291*	0.00012	3.3e-08	−0.000055	0.00008	1.1e-08
Distance to road	−0.00024*	0.00009	8.8e-08	0.000001	0.00012	2.9e-08	0.000025	0.00006	1.4e-09

*Values significantly different from 0.

direct field investigation of the vegetation at migration stopover sites revealed a high prevalence of oak forest *Quercus* spp., as opposed to Sarikamiş forest which is entirely composed of Scots pines (cf. Appendix S5), we deduced that hyperphagia before the winter drove the observed patterns (Noyce & Garshelis, 2011; Seger *et al.*, 2013). This hypothesis was further corroborated by the fact that only wild bears (i.e. those bears that did not use the additional food resources provided by the city garbage dump) migrated. Since migratory trips occurred between September and November, we excluded mating activities (May–July) as an alternative driver for the observed movement patterns. We found no comparable study describing similar food-related migratory movements immediately before hibernation in brown bears. Additionally, while long-distance movements of bears are typically associated with dispersal or translocation events (Liley & Walker, 2015), the observed distances covered by migrating wild bears were remarkable. Our findings thus add valuable information to the life history of the species and a new spatiotemporal dimension to its management and to conservation efforts.

The identification of two behavioral types and information on ranging patterns have far-reaching implications for the regional management and conservation of the species. First, the observed long-distance movements showed that bears living in the SAMNP are potentially connected with the larger bear population of the Black Sea mountains and Georgia (Can & Togan, 2004). Our data also provided further support for the ongoing efforts to create Turkey's first wildlife corridor (Şekercioğlu 2012), with the goal of enhancing connectivity between the SAMNP and wildlife populations in the Black Sea and Georgian forests. Second, the natural resources of Sarıkamış forest may not be sufficient to sustain the local bear population throughout the entire year. Bears had to migrate to find food outside the core study area or to supplement their diet with anthropogenic food resources. Any intervention that would limit either option could have severe consequences at the subpopulation level. Third, following a governmental plan, the city garbage dump will be closed in the near future. We hypothesized three scenarios: (1) dump bears die following malnutrition before hibernation, (2) they resume the migratory behavior observed in forest bears or (3) they seek food in the Sarıkamış city and nearby villages. Given the bears' ability to exploit anthropogenic food resources (Elfström *et al.*, 2012), we anticipate the third scenario, at least in the short term, which is likely to increase the interactions and existing conflicts with people (Chynoweth *et al.*, 2016). To limit interactions and avoid fatalities, the closure of the dump should therefore be coupled with the measures such as the use of bear-proof bins and daily removal of household leftovers (Robbins, Schwartz & Felicetti, 2004). In the long term, after the dump closure, the persistence of the bear population of the Sarıkamış forest will depend on the bears' migratory possibility. Conservation efforts should therefore aim to secure and facilitate their migratory movements to the foraging grounds prior to hibernation. Given the population-level selection for forested habitat, this can be achieved through the reforestation of the proposed wildlife corridor and should be accompanied by education efforts to enhance bear acceptance by the local population along the observed migratory route.

We also demonstrated that animals' movements and use of the surrounding landscape largely depend on their movement phase. Our study thus provides further evidence that the source of the data used to model animals' habitat selection is as important as the type of predictor environmental variables considered (Zeller, McGarigal & Whiteley, 2012; Elliot *et al.*, 2014). We showed that during the roaming phase bears were less selective in their habitat choice compared to the sedentary phase. Differences in habitat selection between resident and roaming individuals (in the specific case of dispersers) have been reported for other species (Elliot *et al.*, 2014; Killeen *et al.*, 2014). While during the sedentary phase individuals may select habitats based on the 'known' distribution of food, shelter and mates, during the roaming phase, they are more naïve to the landscape matrix they move through. Forest appeared, however, to be equally important in each phase. Being a prominent landscape feature, forest can be easily recognized in the distance during migratory trips through unknown landscapes, and actively selected for. The selection of locations closer to roads during the sedentary phase around Sarikamiş forest may be due to the presence of additional food resources deriving from intensive picnic activities (pers. observ.), but further investigation is necessary. Including not only nonlinear responses of distance to roads but also of distance to villages and elevation, could help further understand the mechanisms of habitat selection. We caution for over interpretation of the results for the roaming and stopover phase due to the moderate model performance (see Appendix S3, for further considerations).

To summarize, we showed that the availability of a human-related source of food can cause a behavioral dichotomy among individuals of a confined population. This inter-individual variation is manifested in alternative feeding habits, movement pattern and selection of different habitat types. Therefore, identification and consideration of observed variation in behavioral types is fundamental for the correct implementation of evidence-based conservation strategies. Failures to detect such differences could result in the erroneous allocation of limited conservation resources, such as setting aside portions of land characterized by landscape features that are critical to only particular behavioral types (Simberloff *et al.*, 1992; Beier & Noss, 2008). Finally, because most research on brown bears has been carried out in northern Europe and North America, this work in Turkey increases our understanding of the species living under considerably different environmental, ecological and social conditions. Empirical evidence from this work thus adds valuable information for the implementation of management and conservation strategies of bears not only in Turkey but also worldwide.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Fieldwork and collection of GPS movement data.
Appendix S2. Net squared displacement.
Appendix S3. Step selection function.
Appendix S4. Observed movement paths.
Appendix S5. Vegetation differences between the Sarikamiş forest and the stopover sites.